HANDBOOK

General Electric
Company

A

HANDBOOK

ON

INCANDESCENT LAMP ILLUMINATION

1913

PRICE FIFTY CENTS

Y-177

Mazda Lamps For Standard Lighting Service

100-130 Volts

Straight side bulbs

15, 20, 25, 40, 60, 100, 150, and 250 watts.

Round bulbs

15, 25, 40, 60, 100, 150, 400, and 500 watts.

200-260 Volts

Straight side bulbs

25, 40, 60, 100, 150, and 250 watts.

Round bulbs

25, 40, 60, 100 and 500 watts.

(For complete schedule of Mazda lamps, see pages 65 and 66)

PREFACE

In preparing this book the object has been to provide a ready reference for those interested in incandescent lamps and in problems dealing with incandescent lamp illumination. With this in view there have been included tables and formulæ covering the various problems that may present themselves to the central station man, to the lamp solicitor, to the student, and to the user of incandescent lamps.

As this is the first publication of this nature, it is to be expected that some sections will contain superfluous matter, while others will not be covered thoroughly enough to meet the requirements as intended. Suggestions, criticisms and corrections from those who find use for this book are earnestly solicited, as such will help materially in the preparation of future editions.

CONTENTS

Dictionary of Terms Used

The **Actual Life** of a lamp is the number of hours it burns before its filament breaks, or before it becomes useless.

Ampere. The unit of electric current strength is the ampere. It is that current which, when passed through a solution of silver nitrate in a silver voltameter, will deposit silver at the rate of .001118 grams per second. It is the amount of current flowing through a resistance of one ohm under a pressure of one volt.

Candle-Power is the unit of intensity of light emitted from a lamp or other light source. (See "Candle-Power Relations" for further discussion).

The **Cold Resistance** of a filament is its resistance at 0° centigrade.

Efficiency as applied to incandescent lamps is usually expressed in watts per candle. (See "Candle-Power Relations.")

Fechner's Fraction is the minimum fractional difference between any two luminosities which the eye can perceive. This ability to discern difference in luminosities depends on the capacity of the eye to determine shade perception. The value of this fraction attains its normal value, that is, the eye is at its full sensitiveness when the illumination is about 1 foot-candle. (See page 83.)

The **Flux Factor** or lumen constant for any given zone is the constant which multiplied by the average candle-power in that zone gives the total quantity of light expressed in the lumens emitted in that zone.

Glare is a condition of brilliancy of light sources or illuminated surfaces, whereby ocular discomfort or interference with vision results. Glare is likely to occur when a bright light or excessive contrast of intensity intrudes in the field of vision.

Illumination, as generally used in a technical sense, refers to luminous radiation falling on surfaces in contradistinction to the light emitted from a lamp.

Intensity of Illumination is measured in foot-candles, one foot-candle being the intensity incident at right angles upon a plane one foot distant from a point source of one candle-power.

Flux of Illumination is measured in lumens and is equal to the intensity of the illumination multiplied by the area over which it is distributed, i. e., lumens = foot-candles × square feet.

Intrinsic Brilliancy, or surface brilliancy, is the intensity of light emitted from a source per unit of its projected area. It is usually expressed in candle-power per square inch.

Kelvin's Law. The most economical area of a conductor is that for which the annual cost of energy wasted is equal to the annual interest on that portion of the capital outlay which represents the cost of metal used. (See example page 100.)

The **Kilowatt** is 1000 watts.

Lumen. (See "Candle-Power Relations.")

Luminous Efficiency denotes the ratio of the luminous radiation of an illuminant to its total radiation.

The **Mean Horizontal Candle-Power** is the average of the candle-powers in the horizontal plane in all directions about a lamp whose axis is vertical.

The **Mean Spherical Candle-Power** is the mean of the candle-powers in all directions about a lamp.

Mean Zonular Candle-Power is the average candle-power given off in the particular zone in question.

The **Micron** is the unit of light wave length and is equal to .001 mm.

A **Mil** is .001 inches.

A **Circular Mil** is the area of a circle 1 mil in diameter. The area of any conductor in circular mils is equal to the square of its diameter in mils, or to 1,000,000 times the square of its diameter in inches. 1 sq. mil is equal to 1.273 times one circular mil.

The **Net Efficiency** of an illuminant is the ratio of the luminous energy to the total energy consumed.

Ohm. The unit of resistance is the ohm and is the resistance that would be offered to the flow of an electric current by a column of mercury 106.3 cm. in length, and 14.4521 grams in mass.

A **Photometer** is a device used to compare the candle-powers of light sources. The simple photometer consists of two lamp receptacles, one at either end of a scale called the photometer bar. Between these receptacles is a movable sight box for comparing the light intensities incident on the screen contained therein.

Purkinje Effect. If a red field and a blue field are illuminated so as to appear of about the same brightness, and then the intensity of illumination on both be greatly reduced in the same proportion, the red field will appear darker than the blue; and conversely, if the intensity be greatly increased the red will appear brighter.

Selective Radiation occurs where a surface emits radiation of the various wave lengths in different proportions from that of a theoretically black body at the same temperature.

The Spherical Reduction Factor is the ratio of the mean spherical candle-power to the mean horizontal candle-power.

Temperature Coefficient. The resistance of a filament changes by the addition (or subtraction) of a certain percentage of the cold resistance for each degree of temperature change. This percentage is called the temperature coefficient. The formula for finding the resistance at any temperature is

$$Rt = Ro + Ro\ a\ t$$

where Ro = the cold resistance
a = the temperature coefficient
t = the degrees centigrade at which Rt is to be found.

The **Useful Life** of a lamp is the number of hours it burns before it drops to 80% of its initial candle-power.

The **Visible Spectrum** includes wave lengths varying from approximately 0.4 microns to 0.8 microns.

Visual Acuity is the ability to observe detail. Acuity is measured by the ratio of the distance at which the eye can discern the details of a standard letter to the distance regarded as standard for that letter. (See article, page 83.)

The **Volt** is the unit of electro-motive force or electrical pressure. It is the pressure necessary to force a current of one ampere through a resistance of one ohm.

The **Watt** is the unit of electrical power; it is the product of instantaneous values of electromotive force and current in the circuit when their values are respectively one volt and one ampere.

The **Watt-Hour** is the unit of electrical energy, and is the product of power and time.

Formulæ

OHM'S LAW FOR DIRECT CURRENT

$$E = I\ R$$

Volts = amperes × ohms
Amperes = volts ÷ ohms
Ohms = volts ÷ amperes

Series Circuit

$$R = r_1 + r_2 + r_n$$
$$E = e_1 + e_2 + e_n$$

R is the total resistance of the circuit and is the sum of the resistances of sections of the circuit.

E is the total wattage and is the sum of the voltage drops across the resistances r, r_2 and r_n.

Shunt or Multiple Circuit

$$I = i_1 + i_2 + i_3$$
$$E = e = e_2 = e_3$$
$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}} = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2}$$

Parallel and Series Circuit

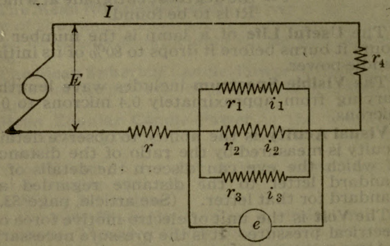


Fig. 1

$$I = i_1 + i_2 + i_3$$
$$E = Ir + e + Ir_4$$
$$e = i_1 r_1 = i_2 r_2 = i_3 r_3$$

Power in Direct Current Circuits

Watts = volts × amperes
Amperes = watts ÷ volts

OHM'S LAW FOR ALTERNATING CURRENT

$E = IZ$
Volts = amperes × impedance ohms
Z = impedance ohms $= \sqrt{R^2 + X^2}$
R = ohms resistance
X = ohms inductive reactance

The voltage drop due to inductive reactance is 90° ahead of the IR drop and the impedance drop is the resultant of the two. When represented graphically the IZ drop is the diagonal of the parallelogram constructed on the IX and IR drops. As the diagonal is equal to the square root of the sum of the sides squared,

$$IZ = \sqrt{\overline{IR}^2 + \overline{IX}^2}$$

The common factor I cancels out so that

$$Z = \sqrt{R^2 + X^2}$$

Power in Alternating Current Circuit

Watts = volts × amperes × power-factor

The power-factor is the cosin of the angle between the impedance volts IZ and the voltage drop IR and is equal to $\frac{R}{Z}$.

Conversion Factors

1 h.p. = { 746 watts; 33,000 ft. lbs. per min.

1 watt = { .00134 h.p.; .001 kw.; .736 ft. lbs. per sec.; 44.24 ft. lbs. per min.

1 ft. lb. = { .000000377 kw-hrs.; .0000005 h.p. hrs.

1 kw. = { 1000 watt; 1.34 h. p.; 2,655,400 ft. lbs. per hr.; 229 lbs. of coal oxidized per hour

1 kw-hr. = { 1000 watt hours; 1.34 horse-power hrs.; 2,655,400 ft. lbs.; 229 lbs. of coal oxidized with perfect efficiency.

1 h.p.-hr. = { .746 kw-hr.; 1,980,000 ft. lbs.; 172 lbs. of coal oxidized with perfect efficiency.

Calculation of Lamp Data

Candle-power = watts ÷ watts per candle

Candle-power = volts × amperes ÷ watts per candle

Candle-power = ohms × (amperes) ^{2} ÷ watts per candle

Watts = candle-power × watts per candle

Watts per candle = watts ÷ candle-power

Amperes = candle-power × w.p.c. ÷ volts

Ohms = watts ÷ (amperes) ^{2} = candle-power × w.p.c. ÷ (amperes) ^{2}

Volts = watts ÷ amperes = candle-power × w. p.c. ÷ amperes

Mean spher. C.P. = mean hor. C.P. × mean spher. C.P. factor

$$\text{Mean spher. C.P. factor} = \frac{\text{Mean spher. C.P.}}{\text{Mean hor. C.P.}}$$

$$\text{Mean hor. C.P.} = \frac{\text{Mean spher. C.P.}}{\text{Mean spher. C.P. factor}}$$

Total cost of lighting (renewal cost and cost of power) for any given number of hours H. is equal to

$$\left\{\frac{\text{H} \times \text{Price of Lamps}}{\text{Total life}}\right\} + \left\{\frac{\text{H} \times \text{Initial watts}}{1000} \times \text{Cost of power per kw-hr.}\right\}$$

Method of Photometering Incandescent Lamps

As all lamps must be photometered and labeled with the voltage at which they give the required candle-power, it is necessary to have working standards with which they may be compared in order that the rating be uniform. These standard lamps are carefully selected and rated on an accurately designed precision photometer, and are then checked by the Electrical Testing Laboratories.

It is quite possible to determine when the two sides of a screen are illuminated to the same intensity, when some arrangement is made whereby both sides can be viewed at the same time. This, combined with the law of inverse squares, forms the basis of all photometering methods. A working standard, made as explained above, is set in a revolving holder at one end of a photometer bar, and the voltage is adjusted on a lamp at the other end, known as the back standard, until equal intensities are observed on the screen. If it is desired to "set" this back standard for the same candle-power as the standard lamp, the screen must be halfway between the two lamps, that is, in the equation,

$$\frac{C.P._1}{C.P._2} = \frac{d_1^2}{d_2^2} \quad \text{the ratio} \quad \frac{d_1^2}{d_2^2} \quad \text{must be unity.}$$

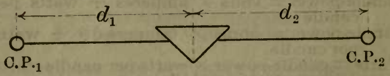


Fig. 2

After "setting" the back standard, the working standard is replaced by the lamp to be rated, and the voltage is adjusted on this lamp until a "balance" is obtained on the screen. That voltage is marked on it as the voltage at which it will give its rated candle-power. With a little experience the operator soon becomes an accurate reader, being able to check her readings with little or no variation.

Photometer Heads

The types of photometers in most general use are those employing the Bunsen and the Lumner Brodhun sight boxes and the flicker photometer.

In the Bunsen sight box, mirrors are arranged so that both sides of a screen can be observed at the same time. The screen is made of white opaque paper with a sharply defined translucent spot, usually made with paraffine, in the center. The Leeson disc is a slight improvement over the Bunsen screen. This consists of a translucent disc between two opaque discs with two star shaped apertures opposite each other. Although they are not the most accurate sight boxes, they are the least tiring to the eyes when used continually.

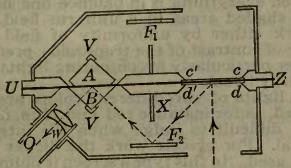
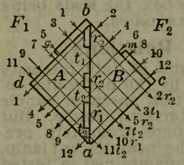


Fig. 3

The Lumner Brodhun Screen is a far more satisfactory form for precise work. It is somewhat intricate as will be seen from Fig. 3 which shows the sight box in plan. The box is mounted on the photometer bar with its axis of rotation *U Z* perpendicular thereto. The screen proper *c, c', d, d'* is a disc of compressed magnesia which gives a brilliant matt surface upon which the rays from the sources of light to be compared fall normally. This screen is simultaneously viewed from both sides by the help of the mirrors F_1, F_2 and the right angled prisms, *A*, *B*, shown in plan in Fig. 4. Prior to cementing together the hypothenuse faces of these prisms, the surface of *A* is recessed by sand-blasting in vertical strips



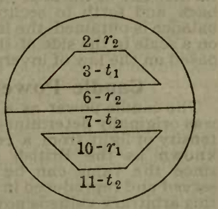


Fig. 4

Fig. 5

as shown. When the prisms are cemented, the spaces between the strips are transparent, but at

the strips there is a total reflection for light entering normal to the free prism faces. Therefore the odd numbered rays (Fig. 4) received from $c\ c'$ via F_1 enter the sight field only through the cemented faces, and the even rays from $d\ d'$ via F_2 only by total reflection at the strips. The arrows in the figure show plainly the course of the rays. The result is a field resembling Fig. 5. each half circle receiving light from one side of the screen and having superposed upon it a trapezoidal area received from the other side of the screen. These areas are slightly darkened by absorption from the glass strips *mc* and *gb*, so that when everything is in balance one has two equally shaded areas in a uniform field. One can work either by uniformity of field or by equality of contrast of the trapezoids, preferably the latter particularly in comparing lights differing slightly in color.

When lights of two different colors are to be compared, as for instance red and blue, it is extremely difficult to judge when the intensities are equal. For precise work the flicker photometer is used. In this type a screen is illuminated by the two sources of light in rapid alternation. When the speed is adjusted between 10 and 20 alternations per second the illumination appears to flicker until the intensities of the two become equal, or the flash from one bridges over the gap to the flash from the other.

The Sharp Millar Illuminometer is used quite extensively as a portable instrument. A compartment at one end of the blackened interior contains a Lumner Brodhun prism. At this end of the box is an elbow tube, the top of which is fitted with a diffusing cap of milk glass. A mirror is placed at the elbow of the tube which reflects the light rays to the Lumner Brodhun prism set, where they are redirected to the eye-piece in the side of the box. The other end of the prism compartment contains a milk glass window illuminated from behind by a comparison lamp at the further end of the box. This lamp can be moved back and forth to secure a balance. When a balance is obtained, the intensity is read directly on a scale in the side of the box, the scale being based on the law of inverse squares.

Candle-Power Relations

The candle-power as a unit of light intensity was originally determined by the horizontal intensity of light from a certain specified candle known as the British standard candle. But since the value can be more accurately preserved and reproduced in the incandescent lamp, this arbitrary value is now maintained in tested incandescent lamps in the U. S. Bureau of Standards at Washington and in other laboratories. The present standard in general use in the United States, Great Britain, France and other

countries (Germany excepted), is the International Candle-power, which was established at the International Conference of 1909. It is 1.6% less than the British candle used in this country. Thus 16 British candle-power corresponds to 16.26 International candle-power.

The relations of the International Candle to other terms are as follows;

1 International Candle = 1 American Candle United States).

1 International Candle = 1 Pentane Candle (Great Britain).

1 International Candle = 1 Bougie Decimale or 0.104 Carcel Units. (France).

1 International Candle = 1.11 Hefner Units (Germany).

For a more detailed description reference is made to U. S. Bureau of Standards Circular No. 15, dated May 20, 1909.

In the case of the incandescent lamp it has become customary to rate a lamp in terms of the mean horizontal candle-power with clear bulb and no reflectors.

The horizontal candle-power measurement was adopted simply because it was the customary and most convenient method of measuring the light intensity of gas, oil, and candle flames, which burn generally in a vertical direction. Incandescent lamps, however, may be used in any and every position, and in addition it is possible to alter considerably the distribution of light from an incandescent lamp by the simple process of changing the shape of the filament. As horizontal measurement of candle-power disregards all light emitted save that emitted in a horizontal direction, and as light sources giving widely different total amounts of light may emit the same amount of light in a horizontal direction, it obviously follows that this method of candle-power measurement is incomplete, especially when lamps of different types of filaments are compared. Furthermore, with any type of lamp the intensity of light varies in different directions, particularly for various angles of elevation. It is moreover modified by the use of globes and reflectors. Therefore a candle-power rating of a lamp has no value (except in the case of a standard type of incandescent lamp) unless the equipment used and the candlepower referred to are fully described.

A full and complete measure of candle power requires consideration of the light given in all directions, or at all points of a sphere surrounding the lamp. If we take the mean of all these candle-power values we have what is termed the mean spherical candle-power. The mean spherical candle-power may then be considered as a measure of the total flux of light.

M. S. C. P. $\times 4\pi =$ total lumens emitted.

The complete measurement of spherical candle-power of incandescent lamps involves considerable work with special apparatus. It is possible, however, to express approximately the mean spherical candle-power in terms of the mean horizontal candle-power and a spherical reduction factor.

The spherical Candle-power Factor or Reduction Factor of a lamp is the ratio of its Mean Spherical to its Mean Horizontal Candle-power, or

Mean Spher. C. P. ÷ Mean Horiz. C. P.

Example: – The Spherical Candle-power Factor of a lamp whose Mean Horizontal Candle-power is 33.9, and whose Mean Spherical Candle-power is 26.44, is equal to 26.44 ÷ 33.9 = .78.

The Spherical Reduction Factors for tungsten filament and metallized filament lamps are as follows:—

Mazda	
Compensator type	.79
Tubular	.78
Train Lighting	.80
Round Bulb, 15 W–250 W, 100–130 volt	.78
All other large styles	.79
Gem	
Regular	.825
Train Lighting	.815

The Mean Horizontal Candle-power is the mean of the candle-power in all directions either above or below the horizontal. When above it is designated as mean upper hemispherical candle-power. Mean lower hemispherical candle-power, i.e., below the horizontal, is understood when merely mean hemispherical candle-power is specified. This unit is then a measure of the flux of light in its hemisphere. Lumens (in lower hemisphere) $= 2\pi$ M. Hemispherical C.P.

The lumen is the unit of the flux either of light or of illumination, and is equal to the intensity distributed over one unit of space. Ex.-Lumens (of light) = C.P. × radians of solid angle. There are 4π radians in a sphere so that the total lumens from any light source = Mean Spherical C.P × 4π Lumens (of illumination) = foot candles × square feet of area.

The lumens of light correspond directly to those of illumination, so that if all the lumens from a light source fall upon a surface, the lumens of light and of illumination will be equal.

For practical service and in the commercial rating of lamps the mean horizontal candle-power is still in use, but in testing and comparing lamps of different shape filaments the mean spherical candle-power should be considered for the following reasons which apply to lamps of any one class of filament.

The life and candle-power performance of a

lamp depend upon the temperature of its filament. It is not practicable to measure this temperature in degrees, and since with similar conditions of vacua and filament surfaces the temperature is indicated by the consumption of power per candle or watts per candle, we utilize watts per candle as a basis for determining relative temperatures or the relative measure of strain upon filaments while operating.

As watts per candle is a ratio of watts consumed to total candle-power given, it is apparent that the method of obtaining the candle-power has an important bearing in determining the relative strain. When the horizontal candle-power is taken, the watts per candle determine the relative strain correctly, only when the filaments are exactly alike in shape. With spherical candle-power, however, the watts per candle determine correctly the relative strain between filaments no matter what their size or shape. If, therefore, a test be made between lamps having filaments differing in shape, we must compare them at the same watts per mean spherical candle-power and not at the same watts per mean horizontal candle-power. This can be accomplished by either of two methods, viz.:—

1. By testing the lamps at the same watts per mean spherical candle-power, or
2. By testing the lamps at the same watts per mean horizontal candle-power, and calculating their lives at the same watts per mean spherical candle-power by means of their spherical and horizontal candle-powers and their life factors, Ex.:—

Suppose two lamps, A and B, are placed on test at 1.23 watts per Mean Horizontal Candle-power, and that

$$A = \frac{\text{Mean Hor. C. P.}}{\text{Mean Spher. C. P.}} = 1.282, \text{ and}$$

$$B = \frac{\text{Mean Hor. C. P.}}{\text{Mean Spher. C. P.}} = 1.208$$

Then

Watts per Mean Spher. C.P. of A $= 1.23 \times 1.282 = 1.577$.

Watts per Mean Spher. C.P. of B $= 1.23 \times 1.208 = 1.486$.

Considering the watts per M.S.C.P. of A as 100%, the watts per M.S.C.P. of B will be 94.3%, and the life factor of B is 68%. Therefore to reduce lamp B to an equal comparative basis with lamp A we must multiply B's result by .68.

Efficiency of a lamp or light source is expressed in terms of specific consumption, or specific output, as watts per mean spherical candle-power, total lumens per watt, lumens per cubic foot of gas or per gallon of oil. In the case of the incandescent lamp it is customary to use watts per

candle-power (Mean Horizontal). Lumens per watt is, however, a more reliable measure and will probably be used to a greater extent, if not altogether in the near future.

The rated or commercial efficiency of a lamp is its initial efficiency or efficiency when new. As the efficiency of a lamp changes during its life it is obvious that its average efficiency is quite different from its initial efficiency and should be carefully distinguished from it.

The candle-power and voltage of a lamp are fixed by its initial efficiency (W.P.C), and the three terms, candle-power, voltage, and watts per candle are necessary for a complete expression of a lamp's rating.

Illumination Calculations

Relations of Foot Candles, Candle-Power, and Distance between the Source of Light and the Surface Illuminated.

Consider a light of 1 candle-power intensity in all directions placed at the center of a hollow spherical shell of 1 ft. radius. This light would illuminate the inner surface with an intensity of 1 ft. candle, and the illuminated area would be $4\pi = (12.56)$ sq. ft., since the surface of a sphere is found by multiplying the square of the radius by the constant 4π. If the same light were placed at the center of a spherical shell of 2 ft. radius, the quantity of light originally distributed over the area of 4π sq. ft. would now be distributed over an area of four times 4π, (50.28) sq. ft. It is readily seen that the illumination on the larger surface would be ¼ of a foot candle, since the total amount of light is the same in both cases, and the larger surface is four times the smaller. A lamp of 16 spherical candle power at the center of the smaller sphere would give an illumination of 16 foot candles on the inner surface. If placed at the center of the larger sphere the illumination on the inner surface would be 4 foot candles. If placed at the center of a hollow sphere of 4 ft. radius the illumination on the inner surface would be 1 foot candle.

If a light source be located at the center of a spherical surface all the light rays emanating therefrom will meet this surface normally; hence, normal illumination in foot candles is found by dividing the candle-power of the source by the square of its distance from the surface illuminated.

Therefore, normal illumination =

$$\frac{\text{Candle-power (c.p.)}}{\text{Distance squared } (d^2)}$$

This rule, known as "The Law of Inverse Squares" does not apply where the light falls obliquely on the surface under consideration, nor where the source is a long line, as the Moore tube.

Calculation of Horizontal Illumination (Point by Point Method)

THIS IS THE FUNDAMENTAL OR BASIC METHOD

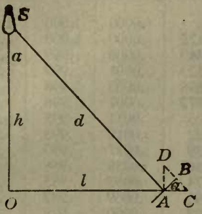


Fig. 6

In practical illumination most of the rays do not meet the surface normally. In Fig. 6 the rays from the lamp shown at "S" are assumed to be normal to the plane "AB". As has been shown the illumination on this plane is

$$I_n = \frac{c.p.}{d^2} \quad \ldots\ldots\ldots (1).$$

C.P. equals candle-power of the lamp at "S"; d equals distance "SA".

But in reality the light that would have been intercepted by "AB" will be distributed over the larger plane "AC". From the triangle ABC

$$\frac{AB}{AC} = \cos a \ldots\ldots\ldots (2) \qquad \text{hence,}$$

$$AC = \frac{AB}{\cos a} \ldots\ldots\ldots (3),$$

that is, the square feet in plane AC is found by dividing the square feet in AB by the cos a. To illustrate, if **a** had such a value as to make its cos equal to .5, the area of the plane AC would be found by dividing that of AB by .5, that is, area AC would be twice as great as AB, and the intensity of illumination would, therefore, be one-half that of AB

Hence the general rule that since the area of the oblique plane AC is obtained by dividing that of the normal plane AB by cos a, the illumination of AC is that of AB multiplied by cos a, or for oblique illumination,

$$I_h = \frac{c.p.}{d^2} \cos a \ldots\ldots\ldots (4)$$

But from the triangle OSA

1. Table of Angles, Sines and Cosines.

a^o	sin a	$\sin^3 a$	cos a	$\cos^2 a$	$\cos^3 a$
0	.0	.0000	1.000	1.000	1.000
1	.0175	.0000	1.000	1.000	1.000
2	.0349	.0000	.999	.999	.998
3	.0523	.0001	.999	.997	.996
4	.0698	.0003	.998	.995	.993
5	.0872	.0007	.996	.992	.989
6	.105	.0011	.995	.989	.984
7	.122	.0018	.993	.985	.978
8	.139	.0027	.990	.981	.971
9	.156	.0038	.988	.976	.964
10	.174	.0052	.985	.970	.955
11	.191	.0069	.982	.964	.946
12	.208	.0090	.978	.957	.936
13	.225	.0114	.974	.949	.925
14	.242	.0142	.970	.941	.913
15	.259	.0173	.966	.933	.901
16	.276	.0209	.961	.924	.888
17	.292	.0250	.956	.915	.875
18	.309	.0295	.951	.905	.860
19	.326	.0345	.946	.894	.845
20	.342	.0400	.940	.883	.830
21	.358	.0460	.934	.872	.814
22	.375	.0526	.927	.860	.797
23	.391	.0596	.921	.847	.780
24	.407	.0673	.914	.835	.762
25	.423	.0755	.906	.821	.744
26	.438	.0843	.899	.808	.726
27	.454	.0936	.891	.794	.707
28	.470	.104	.883	.780	.688
29	.485	.114	.875	.765	.669
30	.500	.125	.866	.750	.650
31	.515	.137	.857	.735	.630
32	.530	.149	.848	.719	.610
33	.545	.162	.839	.703	.590
34	.559	.175	.829	.687	.570
35	.574	.189	.819	.671	.550
36	.588	.203	.809	.655	.530
37	.602	.218	.799	.638	.509
38	.616	.233	.788	.621	.489
39	.629	.249	.777	.604	.469
40	.643	.266	.766	.587	.450
41	.656	.282	.755	.570	.430
42	.669	.300	.743	.552	.410
43	.682	.317	.731	.535	.391
44	.695	.335	.719	.517	.372
45	.707	.354	.707	.500	.354

Table of Angles, Sines and Cosines—Continued.

a^o	sin a	$\sin^3 a$	cos a	$\cos^2 a$	$\cos^3 a$
46	.719	.372	.695	.483	.335
47	.731	.391	.682	.465	.317
48	.743	.410	.669	.448	.300
49	.755	.430	.656	.430	.282
50	.766	.450	.643	.413	.266
51	.777	.469	.629	.396	.249
52	.788	.489	.616	.379	.233
53	.799	.509	.602	.362	.218
54	.809	.530	.588	.345	.203
55	.819	.550	.574	.329	.189
56	.829	.570	.559	.313	.175
57	.839	.590	.545	.297	.162
58	.848	.610	.530	.281	.149
59	.857	.630	.515	.265	.137
60	.866	.650	.500	.250	.125
61	.875	.669	.485	.235	.114
62	.883	.688	.470	.220	.103
63	.891	.707	.454	.206	.0936
64	.899	.726	.438	.192	.0842
65	.906	.744	.423	.179	.0755
66	.914	.762	.407	.165	.0673
67	.921	.780	.391	.153	.0597
68	.927	.797	.375	.140	.0526
69	.934	.814	.358	.128	.0460
70	.940	.830	.342	.117	.0400
71	.946	.845	.326	.106	.0345
72	.951	.860	.309	.0955	.0295
73	.956	.875	.292	.0855	.0250
74	.961	.888	.276	.0760	.0209
75	.966	.901	.259	.0670	.0173
76	.970	.914	.242	.0585	.0142
77	.974	.925	.225	.0506	.0114
78	.978	.936	.208	.0432	.0090
79	.982	.946	.191	.0364	.0070
80	.985	.955	.174	.0302	.0052
81	.988	.964	.156	.0245	.0038
82	.990	.971	.139	.0194	.0027
83	.993	.978	.122	.0149	.0018
84	.995	.984	.105	.0109	.0011
85	.996	.989	.0872	.0076	.0007
86	.9976	.993	.0697	.0048	.0003
87	.9986	.996	.0523	.0027	.0001
88	.9993	.998	.0349	.0012	.0000
89	.9998	1.000	.0175	.0003	.0000
90	1.000	1.000	.0000	.0000	.0000

2. Showing the Intensity of Illumination in Foot-Candles on Horizontal Planes at Points at Various Distances from a Light Source of 1 Candle-Power.

Horizontal distance in feet from point directly under light source to point where intensity of illumination is desired.	HEIGHT OF LIGHT SOURCE IN FEET ABOVE PLANE ILLUMINATED.													
	4	5	6	7	8	9	10	12	14	16	18	20	25	30
0	0:.0625	0:.0400	0:.0278	0:.0204	0:.0156	0:.0124	0:.0100	0:.0069	0:.0051	0:.0039	0:.0031	0:.0025	0:.0016	0:.0011
1	14:.0571	11:.0377	9:.0267	9:.0198	9:.0153	6:.0121	6:.0099	5:.0069	5:.0051	4:.0039	3:.0031	3 .0025	2: 0016	2:.0011
2	27:.0447	22:.0321	18:.0237	16:.0181	14:.0143	12:.0115	11:.0094	9:.0067	9:.0050	7:.0038	6:.0030	6:.0025	5:.0016	4:.0011
3	37:.0320	31:.0252	27:.0199	23:.0158	21:.0128	18:.0105	17:.0088	14:.0063	12:.0048	11:.0037	9:.0030	9:.0024	7:.0015	5:.0011
4	45:.0221	39:.0190	34:.0160	30:.0134	27..0112	24:.0094	22:.0080	18:.0059	16:.0045	14:.0036	13:.0029	11:.0024	9:.0015	8:.0011
5	51:.0152	45:.0141	40:.0126	36:.0110	32:.0095	29:.0083	27:.0072	23:.0054	20:.0043	17:.0034	16:.0028	14:.0023	11:.0015	9:.0011
6	56:.0106	50:.0105	45:.0098	41:.0089	37:.0080	34:.0071	31:.0063	27:.0050	23:.0040	21:.0032	19:.0026	17:.0022	13:.0015	11:.0011
7	60:.0076	54:.0079	49:.0077	45:.0072	41:.0067	38:.0061	35:.0055	30:.0045	27:.0037	24:.0030	21:.0025	19:.0021	15:.0014	13:.0010
8	63:.0056	58:.0060	53:.0060	49:.0058	45:.0052	42:.0052	39:.0048	34:.0040	30:.0033	27:.0028	24:.0023	22:.0020	18:.0014	15:.0010
9	66:.0042	61:.0046	56:.0047	52:.0047	48: 0046	45:.0045	42:.0041	37..0036	33:.0030	29:.0026	27:.0022	24:.0019	19:.0014	16:.0010
10	68:.0032	63:.0036	59:.0038	55:.0039	51.-0038	48:.0037	45:.0035	40:.0032	36:.0028	32:.0024	29:.0021	27:.0018	22:.0013	18: 0009
11	70:.0025	66:.0028	61:.0031	58:.0032	54:.0032	51..0031	48:.0031	42:.0028	38:.0025	35:.0022	31:.0019	29:.0017	23:.0013	19:.0009
12	71:.0020	67:.0023	63:.0025	60:.0026	56:.0027	53:.0027	50:.0026	45:.0025	41:.0022	37:.0020	34:.0018	31:.0016	25:.0012	21:.0009
13	73:.0016	69:.0019	66:.0021	62:.0022	58:.0023	55:.0023	52:.0023	47:.0022	43:.0020	39:.0018	36:.0017	33:.0015	28:.0012	24:.0009
14	74:.0013	70:.0015	67:.0017	63:.0018	60:.0019	57:.0020	54:.0020	49:.0019	45:.0018	41:.0017	38:.0015	35:.0014	30:.0011	25:.0008
15	75:.0011	72:.0013	68:.0014	65:.0015	62:.0016	59:.0017	56:.0017	51:.0017	47:.0016	43:.0015	40:.0014	37:.0013	31:.0010	27: 0008
16	76:.0009	73:.0011	69:.0012	66:.0013	63:.0014	61:.0015	58:.0015	53:.0015	49:.0015	45:.0014	42:.0013	39:.0012	32:.0010	28:.0008
17	77:.0008	74:.0009	71:.0010	68:.0011	65:.0012	62:.0013	60:.0013	55:.0013	50:.0013	46:.0013	43:.0012	40:.0011	34:.0010	29:.0007
18	77:.0006	74:.0008	72:.0009	69:.0010	66:.0011	63:.0011	61:.0012	57:.0012	52:.0012	48:.0012	45:.0011	42:.0010	36:.0009	31:.0007
19	78:.0006	75:.0007	72:.0008	70:.0008	67:.0009	65:.0010	62:.0010	58:.0011	53:.0011	50:.0011	46:.0010	44:.0010	37:.0009	32:.0006
20	79:.0005	76:.0006	73:.0007	71:.0007	68:.0008	66:.0009	63:.0009	59:.0009	55:.0010	51:.0010	48:.0009	45:.0009	39:.0008	34:.0006
25	81:.0002	79:.0003	77:.0004	74:.0004	72:.0004	70:.0005	68:.0005	64:.0006	61:.0006	57:.0006	54:.0006	51:.0006	45:.0006	40:.0005
30	82:.0001	81:.0001	79:.0002	77:.0002	75:.0003	73:.0003	72:.0003	68:.0004	65:.0004	62:.0004	59:.0004	56:.0004	50:.0004	45:.0004
35	....	83:.0001	80:.0002	79:.0002	77:.0002	76:.0002	74:.0002	71:.0003	68:.0003	65:.0003	63:.0003	60 .0003	54:.0003	49:.0003
40	....	....	81:.0001	80:.0001	79:.0001	77:.0001	76:.0001	73:.0002	71:.0002	68:.0002	66:.0002	63:.0002	58:.0002	53:.0002
50	....	....	....	82:.0001	81:.0001	80:.0001	79:.0001	77:.0001	74:.0001	72:.0001	70:.0001	68:.0001	63:.0001	59:.0001

Numbers before colons in each column represent the measure in degrees of the angle included between the light ray and the perpendicular to the plane illuminated.

$$\frac{h}{d} = \frac{SO}{SA} = \cos a \text{.........} (5) \quad \text{or,}$$

$$d = \frac{h}{\cos a} = \text{.........} (6)$$

Squaring, $d^2 = \dfrac{h^2}{\cos^2 a} \text{.........} (7)$

Substituting for d^2 in equation (4)

$$I_h = \frac{c.p.}{h^2} \cos^3 a \text{.........} (8)$$

Equation 8 is known as Lambert's Law and is very useful in the calculation of illumination. In Table 1, are given values of $\cos^3 a$ for different values of **a** from 1 to 90°.

To facilitate the use of the above formula there are given in Table 2, values of illumination on horizontal planes at different heights and at different horizontal distances of a light source of 1 candle-power and also the corresponding angles made by the light rays with the perpendicular to the plane.

Method of Using Table

From the lamp and reflector in use obtain the distribution curve. Take from Table 2 the value (in foot candles) of illumination which a one candle-power light source would produce at the point selected. Also note the angle corresponding to this point. From the distribution curve of the lamp take the candle-power at the corresponding angle. Multiply this value by the illumination value found in the table, and the resulting value will be the illumination, in foot candles at the point selected, of the lamp under consideration.

For example: required the illumination produced by a 60 watt clear Mazda lamp with intensive type Holophane reflector at a point 12 ft. below and 12 ft. to one side of the lamp. From Table 2 the value corresponding to these distances is .0025 foot candles and the corresponding angle is 45°. From the distribution curve of the 60 watt lamp with intensive type reflector on Page 31 the candle-power at 45° is approximately 64. Then $.0025 \times 64 = .16$ which is the illumination at the point selected.

If there be more than one lamp in the room, the illumination produced by each lamp is found in the above manner, and the sum taken for the total illumination at the point under consideration.

Calculation of Vertical Illumination

Suppose it is desired to calculate the illumination I on a vertical plane through A. The light rays that would have fallen on AB will be intercepted by the vertical plane DA.

From triangle ABD

$$\frac{AB}{AD} = \sin a \quad \text{.........(9)}$$

Then

$$AD = \frac{AB}{\sin a} \quad \text{.........(10)}$$

that is, the square feet in AD is found by dividing the square feet in AB by the sin a. To illustrate,—if a had such a value as to make sin a equal to .866 the area of the plane AD would be found by dividing the area of AB by .866. In other words, the area of AD would be 1/.866 times that of AB and the intensity of illumination on AD would equal .866 of that on AB.

In general then, the intensity of illumination on a vertical plane is equal to that on the normal plane, multiplied by the sin a

$$\text{or } I_v = \frac{c.p.}{d^2} \sin a \quad \text{.........(11)}$$

From triangle OSA

$$\frac{OA}{SA} = \frac{l}{d} = \sin a \quad \text{.........(12)}$$

$$\text{or } d = \frac{l}{\sin a} \quad \text{.........(13)}$$

$$\text{squaring, } d^2 = \frac{l^2}{\sin^2 a} \quad \text{.........(14)}$$

then in equation (11)

$$I_v = c.\,p.\,\sin^2 a \div \frac{l^2}{\sin^2 a} \quad \text{........(15)}$$

$$= \frac{c.p.}{l^2} \sin^3 a \quad \text{.........(16)}$$

The values of $\sin^3 a$ are given in Table 1.

Flux of Light Method of Calculating Horizontal Illumination.

For rapid calculation the following tables and formulae will be found convenient:

As stated under "Candle-power Relations," a lumen is the quantity of light required to illuminate 1 sq. ft. area with an intensity of 1 ft. candle. Now from Table 8 can be determined the intensity of illumination in foot candles recommended as satisfactory for various classes of service. The floor area of the room is known and the product of foot candles times sq. ft. floor area equals effective lumens required. Having ascertained the effective lumens required, there are two methods by which the number and sizes of lamps necessary can be determined.

The efficiency of an illumination effect can be expressed in effective lumens per watt, which is equal to the foot candles divided by watts per sq. ft. This shows the distinction between total lumens as emitted by a light source

and effective lumens as received on some surface or working plane.

As a result of numerous experiments the effective lumens per watt for various lamps and reflector equipments and conditions of walls and ceilings, has been determined. These values are shown below in Table 3.

3. Effective Lumens per Watt

Lamp	Equipment	Ceiling	Walls	Constant
Mazda	Clear Holophane Refl.	Light	Light	5.0
Mazda	Clear Holophane Refl.	Light	Dark	4.0
Mazda	Clear Holophane Refl.	Dark	Dark	3.4
Gem	Clear Holophane Refl.	Light	Light	2.2
Gem	Clear Holophane Refl.	Light	Dark	1.8
Gem	Clear Holophane Refl.	Dark	Dark	1.5

By dividing the total effective lumens required by the proper constant from the above table, the total wattage required is obtained. This wattage is divided by the necessary number of lamps (method of determining this is shown later) to get the watts per lamp.

The other of the two schemes mentioned above is as follows: Illumination tests have shown that with certain lamps, reflectors, and wall conditions, a given percentage of the total lumens emitted by the lamp reaches the working plane and the percentage is called the illumination constant for that particular equipment (Table 4).

Hence, if the total effective lumens required be divided by this illumination constant, the total lumens emitted by the lamp is determined. Dividing this by the required number of lamps will give the total lumens per lamp. The total lumens given by any of the standard lamps is shown in Table 5.

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4. Illumination Constants

Lamp	Equipment	Ceiling	Walls	Constant
Mazda	Clear Holophane Rfl.	Light	Light	.64
Mazda	Clear Holophane Rfl.	Light	Dark	.51
Mazda	Clear Holophane Rfl.	Dark	Dark	.43
Gem	Clear Holophane Rfl.	Light	Light	.57
Gem	Clear Holophane Rfl.	Light	Dark	.45
Gem	Clear Holophane Rfl.	Dark	Dark	.38

5. Total Lumens Given by Different Types of Incandescent Lamps

Rated Watts	Mazda or Tungsten		Gem	Carbon	
	100–130 V.	200–260 V.	100–130 V.	100–130 V.	200–250 V.
10				21.	
15	112.				
20	151.			50.	
25	185.			84.	
30				96.	
35					84.
40	320.		160.		
45		300.			
50			205.	175.	
60	500.	400.	250.	210.	170.
80			335.		
100	830.	670.	420.	350.	
120				420.	340.
150	1250.	1000.			
250	2170.				
400*	3470.	1670.			
500*	4330.	4030.			

*Round bulb lamps. All other lamps given here have regular type straight sided bulbs.

Determining the Number of Lamps

The area to be lighted should be divided as nearly as possible into equal squares and the light unit placed at the center of each square. The size of the square depends in some cases upon the extent to which shadows will be objectionable and in general the smaller the square the less intense will be the shadows. In lighting large offices where individual desk lights are not employed, the square should be comparatively small in order to have the light on any one desk coming from many units. Table 6 gives the desirable sizes of squares for various classes of service.

Having determined the wattage of the lamps, the number to be used and the spacing, there remains the choice of the reflector.

Choice of Reflector

In selecting a reflector, a careful study of the dimensions of the room is necessary. In general, an extensive type of reflector should be used for stores where there is a single row of lights illuminating both show cases and shelves, also for large areas with low ceiling.

6. Desirable Sizes of Squares.

Kind of Room	Ceiling Height	Desirable Length of Side of Square
Armories	12 to 16 ft.	12 to 16 ft.
Auditoriums	12 to 16 ft.	12 to 16 ft.
Public halls	over 16 ft.	15 to 26 ft.
Rinks	over 16 ft.	15 to 26 ft.
Stores	8 to 11 ft.	8 to 11 ft.
Stores	11 to 15 ft.	10 to 16 ft.
Stores	over 15 ft.	14 to 22 ft.
Offices with individual desk lights	10 to 20 ft.	12 to 18 ft.
Offices without individual desk lights	9 to 12 ft.	7 to 11 ft.
Offices without individual desk lights	12 to 16 ft.	9 to 14 ft.
Offices without individual desk lights	over 16 ft.	11 to 18 ft.

7. Spacing of Units for Uniform Illumination.

Clear Holophane Reflectors, Type	Height above Plane to be lighted
Extensive	1/2 D
Intensive	4/5 D
Focusing	4/3 D

D = Distance between units = Side of square, when units are placed in squares = Average side of rectangle, when units are placed in rectangles

If the area to be lighted is small or requires high intensity of illumination, an intensive reflector is used. Examples may be found in restaurants, department stores, etc.

Focusing reflectors are used in show windows, offices, and other places where high intensities are required.

Table 7 shows the proper height for lamps in terms of distance between units.

Application of the Foregoing Paragraphs

As an example of the above rules, the "flux of light" method is used for the following specific case:

A shoe store 50 ft. x 150 ft. with a 12 ft. ceiling, light ceiling and side walls, lined with shelves containing boxes is to be illuminated.

From the table of foot candle intensities recommended for classes of service,

Shoe stores, 2.0 — 4.0, taking 3 as an average.

Floor area, 50 x 150 = 7500 sq ft.

Effective lumens required, 7500 x 3 = 22.500.

Since prismatic glass reflectors are very efficient, are sufficiently decorative for this class of service, and the Holophane are the best made and most efficient of this class of reflectors, it is applicable here.

First Method

In Table 3 for clear Holophane, light walls and ceiling, the effective lumens per watt are 5. Hence, 22,500 ÷ 5 gives 4500 watts required.

Second Method

The illumination constant (Table 4) for clear Holophane, light ceiling and light walls, is .64. Hence, 22,500 ÷ .64 gives 35,150 total lumens required.

Next, referring to the table of desirable sizes of squares is found,— "stores, 11 to 15 ft. ceiling height, 10 to 16 ft. squares." For a symmetrical arrangement the size of the squares will be taken as 12½ ft., making four rows of twelve lamps each, a total of 48 lamps. Then, 4500 watts ÷ 48 gives 93.8 watts per lamp. Taking the 100 watt lamp as the nearest size. Or 35,150 total lumens ÷ 48 = 732 lumens per lamp. From Table 5 the 60 watt Mazda lamp gives 500 total lumens and the 100 watt 830 total lumens. The 100 watt lamp should be used as it is better to run a little above the calculated value than to drop a marked amount below it.

If it is desired to more closely approach the values calculated, the rows of lamps may be spaced 12½ ft. apart, and in the rows the lamps may be spaced 13½ ft. apart, making a total of 44 — 100 watt lamps.

In a shoe store the plane of illumination is about 1 ft. from the floor, where inspection of the shoes is made, and there must be sufficient diffused light on the boxes to enable the clerk to read the labels. With the above arrangement

of lamps and conditions to be met, the intensive type of Holophane reflector is applicable. The average distance between lamps is 13 ft. As shown in Table 7 the hanging height for intensive reflectors should be 4/5 of the distance between lamps.

4/5 × 13 = 10.4 or, say, 10½ ft. from the working plane or the surface to be illuminated. The lamps should then be hung about 11½ ft. from the floor.

As a summary of the foregoing calculations,—44 — 100 watt bowl frosted Mazda lamps, equipped with intensive, clear, Holophane reflectors, form H holders, spaced 12½ x 13½ ft., hung with the center of the lamp about 11½ ft. from the floor.

8. Foot-Candle Intensities Recommended for Various Classes of Service.

Armory or Drill Hall	2.0
Armory (Cavalry—tan-bark floor)	3.0
Art Gallery (walls)	5.0 —10.0
Auditorium	1.0 — 3.0
Automobile Showroom	3.0 — 6.0
Automobile (interior)	.5 — 1.0
Ball Room	2.0 — 3.0
Bank (general)	2.0 — 3.0
Bank (desk work)	4.0 — 6.0
Bar Room	2.0 — 5.0
Barber Shop (over chairs)	3.0 — 6.0
Bath (public)	
Dressing rooms	.7 — 1.0
Swimming pool	1.5 — 2.0
Billboard	5.0 —15.0
Billiard Room (general)	.8 — 1.5
Billiard Room (with distributed and diffused light)	6.0 —10.0
Book Binding.	
Folding, Assembling, Pasting, etc.	2.0 — 3.0
Cutting, Punching and Stitching	3:0 — 5.0
Embossing	4.0 — 6.0
Bowling Alley.	
Alley	1.5
Pins	4.0
Cafe (general illumination only)	2.0 — 4.0
Cafe (lights on tables)	1.0 — 2.0
Canning Plants.	
Pressing Tables	1.0 — 1.5
Filling Tables	1.0 — 1.5
Packing Tables (dried fruits)	1.5 — 2.5
Preserving Caldrons	2.0 — 2.5
Coffee Roasting at Tables	2.0 — 3.0
Assorting Tables	2.5 — 3.0
Packing Tables	1.0 — 2.0

Shipping Rooms	2.0 — 3.0
Card Room	2.0 — 3.0
Carpenter Shop	2.0 — 5.0
Cars.	
Baggage	.7 — 1.0
Day Coach	2.0 — 3.0
Dining (general illumination only)	2.0 — 4.0
Dining (lights on tables)	1.0 — 2.0
Mail	5.0 —10.0
Pullman	2.0 — 4.0
Street	2.0 — 3.0
Church	1.0 — 2.5
Club.	
For various rooms, see Bath, Hotel, Residence, etc.	
Cotton Mill.	
Receiving and Opening Bales	.8 — 1.5
Opening and Lapping	1.0 — 2.0
Carding	1.5 — 2.5
Drawing Frame	1.5 — 2.5
Roving, Spooling, Ring Spinning, etc	2.0 — 3.0
Warping	1.5 — 2.5
Slashing	1.0 — 2.0
Drawing in	2.0 — 4.0
Weaving (light goods)	2.0 — 4.0
Weaving (dark goods	3.0 — 5.0
Dyeing	2.0 — 3.0
Dyeing (inspection)	1.5 — 2.0
Inspecting (general)	5.0 —10.0
Courts.	
Handball	7.0 —10.0
Squash	7.0 —10.0
Tennis	7.0 —10.0
Court Room	2.0 4.0
Dairies and Milk Depots	1.0 — 3.0
Dance Hall	2.0 — 4.0
Depot (see Station Railway).	
Desk	4.0 — 6.0
Draughting Room	6.0 —12.0
Engraving	10.0 —12.0
Factory.	
General illumination only, where additional special illumination for each machine or bench is provided	.8 — 1.5
Local Bench Illumination (fine work)	5.0 —10.0
Local Bench Illumination (coarse work)	3.0 — 5.0
Fire Stations.	
When the alarm is turned in	3.0
At other times	1.0
Forge and Blacksmithing	1.0 — 2.0
Foundry	3.0

Garage	1.0 — 3.0
Gymnasium	1.0 — 3.0
Hall.	
See Auditorium, Corridor of Hote or Office Building.	
Hospital.	
Corridors	.5
Wards (with no local illumination supplied)	1.0 — 3.0
Wards (with local illumination supplied)	.5
Operating Table	12.0 —20.0
Hotel.	
Lobby	2.0 — 4.0
Dining Room (general illumination only)	2.0 — 4.0
Dining Room (lights on tables)	1.0 — 2.0
Writing Room	2.0 — 3.0
Corridor	.6
Bed Rooms	1.5 — 2.0
Lavatory	1.5 — 2.0
Laundry	2.0 — 3.0
Library.	
Stack Room	1.5 — 2.0
Reading Room (with no local illumination supplied)	3.0 — 4.0
Reading Room (with local illumination supplied)	.7 — 1.5
Lodge Room	2.0 — 3.0
Lunch Room	2.0 — 4.0
Machine Shop.	
Machine Tools (fine work)	5.0 — 8.0
Machine Tools (coarse work)	2.0 — 5.0
Buffing and Grinding	2.0 — 3.0
Bench Work. (See Bench Work).	
Assembling and Erecting	1.0 — 3.0
Inspecting	4.0 — 7.0
Market	3.0 — 5.0
Moving-picture Theater	1.0 — 1.5
Museum	2.0 — 4.0
Office Lighting.	
Small Offices (officials)	3.0 — 4.0
Small Offices (desks against walls)	3.0 — 6.0
General Offices (accounting, etc.)	4.0 — 8.0
Opera House. (See Theater).	
Paint Shop (fine work)	4.0 — 8.0
Paint Shop (coarse work)	2.0 — 4.0
Pattern Shop (wood)	3.0 — 5.0
Pattern Shop (metal)	4.0 — 6.0
Pool Room. (See Billiard Room).	
Power House	2.0 — 3.0
Postal Service	5.0 —10.0
Printing.	
Linotype and Monotype	5.0 —10.0
Type Setting	6.0 — 8.0

Composing Stone	6.0 — 8,0
Matrixing and Casting	2.0 — 4.
Proof Reading	3.0 — 5.
Presses	3.0 — 5.
Paper Cutting, Folding, etc	2.0 — 4.
Public Square	.1 — .8
Railway Station.	
Waiting Room	1.5 — 2.5
Ticket Offices, etc. (See Offices).	
Rest Room, Smoking Room, etc.	1,0 — 2.0
Baggage Room	.8 — 1.5
Concourse	.5 — .8
Train Platforms	.5 — .8
Reading (ordinary print)	2.0 — 4.0
Reading (fine print)	3.0 — 5.0
Residence.	
Porch	.2 — 1.0
Porch (reading light)	2.0 — 3.0
Hall (entrance)	.7 — 1.0
Reception Room	1.0 — 3.0
Parlor	1.0 — 3.0
Sitting Room	1.5 — 2.5
Library	2.0 — 4.0
Music Room	2.0 — 3.0
Dining Room	1.5 — 2.5
Dining Room Table (with dome)	3.0 — 5.0
Pantry	1.0 — 2.0
Kitchen	2.0 — 3.0
Laundry	1.5 — 2.0
Hall (upstairs)	.5 — .8
Bed Room	1.0 — 3.0
Bath Room	2.0 — 3.0
Furnace Room	.4 — .8
Store Room	.4 — .8
Restaurant. (See Hotel Dining Room)	
Rink (skating)	1.0 — 3.0
Rug Rack	10.0 —20.0
Saloon. (See Bar Room).	
School.	
Class Room	3.0 — 5.0
Study Room	3.0 — 5.0
Assembly Room	2.0 — 3.0
Office	3.0 — 4.0
Cloak Room	.7 — 1.0
Corridor	.8 — 1.0
Manual Training. (See Carpenter and Machine Shops).	
Laboratory	3.0 — 5.0
Drawing. (See Draughting Room)	
Sewing, Hand (light goods)	3.0 — 5.0
Sewing, Machine (light goods)	4.0 — 6.0
Sewing, Hand (dark goods)	4.0 — 8.0
Sewing, Machine (dark goods)	10 0 —15.0
Shipping Room	2.0 — 3.0
Show Window.	
Dry Goods (high grade)	15.0 —30.0
Dry Goods (ordinary)	10.0 —20.0
Dry Goods (small town)	5.0 —15.0

Miscellany (large city)	10.0 —20.0
Miscellany (small town)	5.0 —10.0
Silk Mills.	
Receiving	1.0 — 2.0
Winding Frames	2.0 — 4.0
Throwing Frames	2.0 — 4.0
Quilling and Warping	3.0 — 5.0
Weaving	4.0 — 6.0
Dyeing	2.0 — 3.0
Dyeing Inspection	15.0 —25.0
Finishing	3.0 — 5.0
Sign. (See Billboard).	
Stable	.4 — 1.0
Stamping and Punching (sheet metal)	2.0 — 5.0
Station, Railroad. (See Railway Station).	
Steel Works.	
Executive and Clerical Offices. (See Offices).	
Drafting Offices	4.0 — 8.0
Machine Shops. (See Machine Shops).	
Unloading Yards	.1 — .3
Open Hearth Floors, Soaking Pits and Cast Houses	.1 — .3
Mould Yard, Skull Cracker Yard and Ore Yard	.1 — .3
Loading Yards (inspection)	.3 — .5
Blast Furnace Cast House	.3 — .5
Rolling Mills	1.0 — 2.0
Wire Drawing	1.0 — 2.0
Threading Floors of Pipe Mills	1.0 — 2.0
Transfer and Storage Bays	.5 — 1.0
Stock Room	.5 — 1.5
Store.	
Art, (Light on Exhibits)	5.0 —10.0
Book	3.0 — 5.0
Baker	2.0 — 4.0
Butcher	2.0 — 4.0
China	2.0 — 3.0
Cigar	4.0 — 6.0
Clothing	4 0 — 7.0
Cloak and Suit	4.0 — 7.0
Confectionery	3.0 — 5.0
Decorator	4.0 — 5.0
Department (see each department)	
Drug	2.0 — 4.0
Dry Goods	4.0 — 7.0
Florist	2.0 — 3.0
Furniture	2.0 — 4.0
Furrier	5.0 — 8.0
Grocery	2.0 — 4.0
Haberdasher, (Men's Furnishings)	5.0 — 7.0
Hardware	2.0 — 4.0
Hat	4.0 — 6.0
Jewelry	4.0 — 6.0
Millinery	4.0 — 6.0
Music	2.0 — 4.0

Notions	3.0 — 5.0
Piano	2.0 — 4.0
Shoe	2.0 — 4.0
Stationery	2.0 — 4.0
Tailor	4.0 — 6.0
Tobacco. (See Cigars).	
Street.	
Business. (not including light from show windows and signs)	.1 — .2
Residence	.0 — 1.1
Telephone Exchange (operators)	2.0 — 3.0
Theater.	
Lobby	2.0 — 5.0
Auditorium	1.0 — 2.5
Warehouse	.5 — 1.0
Wharf	.1 — .7
Woolen Mill.	
Picking Table	2.0 — 4.0
Washing and Combing	3.0 — 4.0
Carding	1.5 — 2.5
Twisting	2.0 — 3.0
Dyeing	2.0 — 3.0
Dyeing (inspection)	15.0 —25.0
Drawing in	2.5 — 4.5
Warping	3.0 — 5.0
Weaving	4.0 — 6.0
Weaving (dark goods)	6.0 — 8.0
Perching	8.0 —15.0

Reflectors for Use with Mazda Lamps.

Good illumination not only requires sufficient light but the proper location and equipment of the lamps, in order that such proper distribution and diffusion of light may result, that the eye is able to see clearly and to the best advantage without strain or glare.

Mazda lamps, due to their construction, give the greatest amount of light in a horizontal direction. Since, in general, the lamp should be located above the line of vision it is necessary to use reflectors to distribute the light properly and direct it upon the working plane.

Reflectors may be divided into two general classes, namely, industrial and decorative. These however overlap, as for instance, the prismatic glass reflector, while under the decorative class, may be well used in an industrial layout.

The industrial reflectors are primarily of metal with reflecting surface of porcelain enamel or aluminum mat, and the decorative reflectors of glass, either prismatic or opalescent.

As excellent examples of these types, description is given herewith in brief of several.

Industrial. *Mazda Mill Diffuser*, made by the General Electric Co., Schenectady, N. Y.

This is a sheet metal reflector, heavily porcelain enameled. The metal is of considerable thickness, and the strength of the reflector remarkable, considerable force being required to even bend it slightly. The porcelain enamel is smooth and of several coats, making an excellent reflecting surface. The diffuser is of a flat cone shape with concentric rings to additionally diffuse the light.

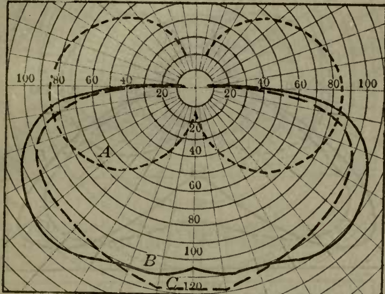


Fig. 7

The distribution obtained is excellent for any general illumination in industrial service, as shown from the accompanying curve (Fig. 7) which is the vertical distribution of candlepower of the 100 watt multiple Mazda lamp with MM 12″ diffuser, form "H" holder: (*a*) clear lamp; (*b*) clear lamp with MM Diffuser; (*c*) bowl frosted lamp with Mazda mill diffuser.

Practically all of the light flux is in the lower hemisphere with the maximum at about 45°.

The following sizes are available:

12″ diameter	25 to 100 watt	Mazda.
16″ "	100 to 250 "	"
21″ "	250 to 500 "	"

Holophane D'Olier, made by the Holophane Works of the General Electric Co.

This is a sheet steel reflector of two finishes: (1) Mat aluminum interior finish with green paint exterior; (2) Porcelain enamel inside and out.

The porcelain enamel has these advantages; it is more readily cleaned resists acid fumes and heat, gives good service in the open and is a slightly better reflecting surface than the aluminum. The enameling of both the Mazda Mill Diffuser and the Holophane D'Olier reflector is

heavy and the metal rigid so that there is no liability of the porcelain being chipped off if hit accidently by the operatives.

The Holophane D'Olier reflector is bowl shaped, made to give two distributions with aluminum finish, namely, extensive and intensive, and for sizes of lamps from 25 to 500 watts. The enamel finish is made to give the extensive distribution only.

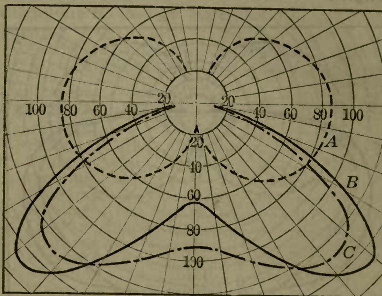


Fig. 8

The above curve (Fig. 8) shows the distribution of the aluminum finish intensive 100 watt D'Olier reflector with 100 watt Mazda: (*a*) bare clear lamp: (*b*) clear lamp with Holophane D'Olier reflector; (*c*) bowl frosted lamp with Holophane D'Olier reflector.

The D'Olier reflector is also made in the aluminum finish in the form of an angle reflector, 15-30-45 and 90° for use in localized machine lighting with the smaller wattage Mazda lamps.

Decorative. The *Holophane Prismatic reflector* is made by the Holophane Works of the General Electric Co. This reflector is typical of the best prismatic glass reflectors, and is applicable for use in offices, stores, dwellings, etc.

This reflector is of a scientific design, the prisms being carefully calculated to direct the light in the required directions to give any desired distribution, which makes it the most efficient decorative reflector on the market. For distribution curves of these reflectors see pages 31, 32 and 33.

The side prisms, besides redirecting the light, serve as a diffusing medium, and allow a small portion of the light to pass through and illuminate the ceiling and side walls.

The standard line of Holophane reflectors is made to give extensive, intensive, and focus-

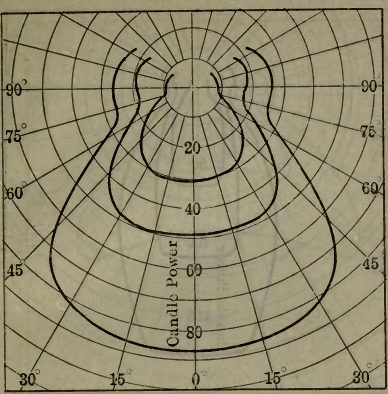


Fig. 9
Mazda Lamps. 25, 40 and 60-watt, 100-130 volt, Bowl-frosted, with Intensive Reflectors.

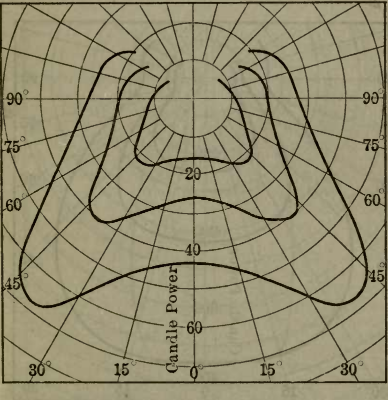


Fig. 10
Mazda Lamps. 25, 40 and 60-watt, 100-130 volt, Bowl-frosted, with Extensive Reflectors.

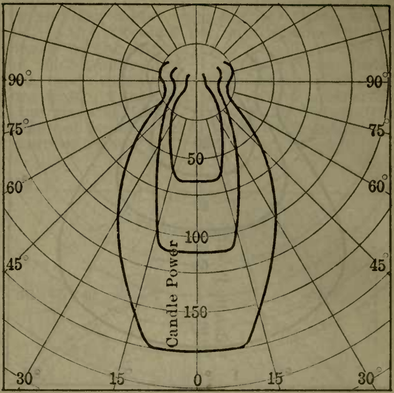


Fig. 11
Mazda Lamps. 25, 40 and 60-watt, 100-130 volt, Bowl-frosted, with Focusing Reflectors.

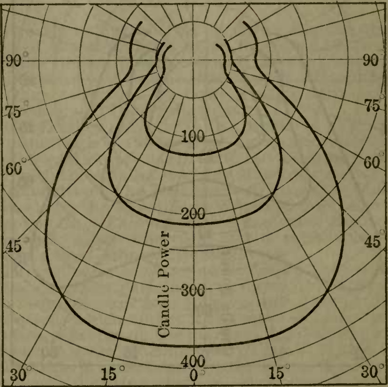


Fig. 12
Mazda Lamps. 100, 150 and 250-watt, 100-130 volt, Bowl-frosted, with Intensive Reflectors.

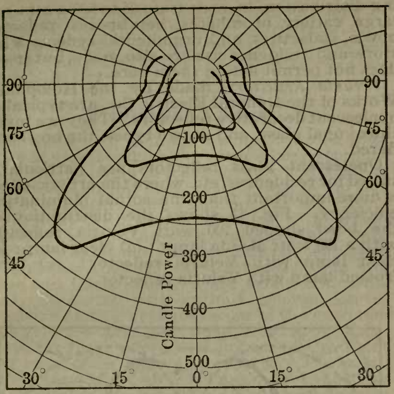


Fig. 13
Mazda Lamps. 100, 150 and 250-watt, 100–130 volt, Bowl-frosted, with Extensive Reflectors.

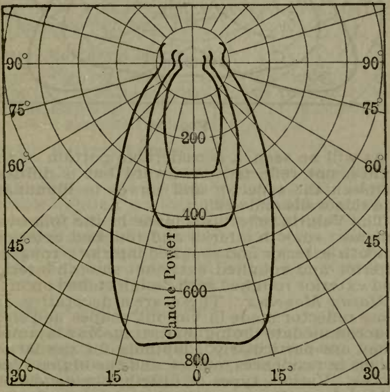


Fig. 14
Mazda Lamps. 100, 150 and 250-watt, 100–130 volt, Bowl-frosted, with Focusing Reflectors.

ing distribution, in sizes from 25 to 500 watts. A large variety of spheres, hemisperes, reflector bowls, stalactites, and ornamental reflectors for store and residence use are also made, but space does not permit listing them here.

Veluria Reflectors, made by the Holophane Works of the General Electric Co., are typical of opalescent decorative reflectors. They are made the of opal glass, and in two types, the bowl and flared.

Opalescent glass reflectors are particularly suited for residences, etc. where the artistic effect is more important than the actual illuminating efficiency. Fig. 15 shows the distribution of the bowl shaped 100 watt Veluria reflector, with a 100 watt Mazda lamp. (*a*) clear lamp; (*b*) clear lamp with Veluria reflector; (*c*) bowl frosted lamp with Veluria reflector.

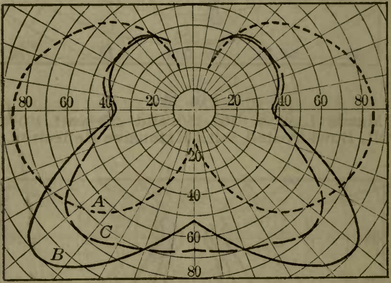


Fig. 15

As will be seen, a considerable portion of the light is not reflected downward but is diffused through the reflector and serves to illuminate the side walls and ceiling.

The Veluria reflector is made in the following finishes: smooth interior and roughed exterior; smooth exterior and roughed interior; roughed interior and roughed exterior: smooth interior and exterior roughed with design etched upon it.

Mazda Monolux. These are a decorative art glass reflector made in various shapes and sizes to accommodate the higher wattage Mazda lamps. They are particularly adaptable for the larger rooms in residences, offices, and the higher class stores. Various types of distribution can be obtained, depending upon the shape of the reflector. It is made for both the direct and semi-indirect systems of illumination, and is exceedingly ornamental.

Distribution curves of any combinations of lamps and reflectors, or other information, may be obtained from the General Sales Office of the Edison Lamp Dept., General Electric Co., Harrison, N. J.

Miniature Lamps

The subject of miniature lamps covers a wide range of uses for which the various lamps coming under this heading are employed. The field of decorative lighting demands the use of various sizes of Miniature lamps to bring out the effects in harmony with the decorations with which they are used. Churches, libraries and residences are made more cheerful by the soft glow of candelabra lamps. At Christmas time the house and Christmas tree are safely and artistically decorated with various colored lamps. Dentistry and surgery make use of the extremely small lamps which may be inserted in incisions, furnishing light where it is impossible to direct light rays from any other source. The small battery capacity of these lamps makes their use possible under all conditions. The United States Government makes use of a great number of miniature lamps in various instruments, and in the sighting of large guns. Telephone switchboards are equipped with small lamps, by means of which the operator is signalled by the subscriber. In short, the Miniature lamp, in some shape or style, meets almost every demand in the field of small lighting.

General Battery Lamps

Mazda General Battery lamps are made for use primarily on battery circuits, but they may be used on any low voltage circuit, or in series on circuits of standard voltage.

Novelty Battery Lamps

Mazda Novelty Battery lamps are used with dry batteries in all kinds of ornamental and portable lighting devices. The Mazda filament emits very little heat, gives a very brilliant light and requires but little battery capacity. These characteristics make it especially desirable for all the lighting devices in which the Novelty Battery types are employed.

Lamps—20 Volts and Below

The low voltage besides permitting the use of a short sturdy filament in the low volt lamp, provides for the production of low candle-power with low wattage consumption.

Automobile and Electric Vehicle Lamps.

Electric lamps have two important advantages for Automobile Lighting; safety and conven-

ience. The fact that the foremost car manufacturers are equipping their cars with electric lights is proof that these advantages are real and not fancied. With the electrically equipped car there is no annoyance in lighting lamps and no fire risk from high pressure gas. A better focus can be obtained with the electric lamp, as the excessive heat of a gas flame prohibits the placing of same deep enough in the reflector to use the greater part of the light, while the low heat of the electric light permits its being set back in a deep reflector. Furthermore, the electric headlight is concentrated into practically a point at the focal center and remains steady and in focus, as it cannot flicker or be blown out of focus by the wind. The interior equipment of a limousine shows the convenience and beauty of electric lamps as applied to auto lighting.

The standard voltage adopted by manufacturers for auto lighting is 6 volts. This low voltage permits the use of a short metallic filament of a comparatively large cross section. The side lights are supplied in G-8 and G-10 bulbs in candle-powers of 3, 4 and 6, and of 3, 6 and 8 respectively. In the P-8 and P-9 bulbs, also used as side lights, the candle-powers are 4 and 6, and 6 and 8. The rear lights are furnished in G-8 bulbs 1-½ candle-power, and in G-6 bulbs in 1-½, 2 and 3 candle-power. The headlight is equipped with a vertical coil filament and furnishes 9, 12, 15 and 18 candle-power in the G-12 bulb, and 15, 18, 21 and 24 candle-power in the G-16-½ bulb. It has an efficiency of 1 watt per candle. The standardized focal length for parabolic reflectors is 1″ and the filament mounted in the G-12 or G-16-½ bulb meets this requirement. These lamps are furnished either with a standard candelabra base or with a bayonet candelabra base. The latter is more generally used, and is recommended because there is no possibility of its jarring out of the socket.

For electric vehicle service the General Electric Co. offers a complete line of electric vehicle lamps, ranging from 21 to 65 volts in G-16½ (2 1/16″ diam.), and 21 to 90 volts in G-18½ (2 5/16″ diam.) round bulbs. These are made in 15 and 25 watt sizes and operate at an efficiency of 1.23 W. P. C.

Current Supply Systems

There are three distinct systems in general use for supplying energy; the storage battery, the

generator and storage battery, and the magneto system. With the storage battery system, the six volt battery is in general use, although electrically driven machines operate the lights on various voltages, according to the make of the machines. Although it is not practical to operate lights on ignition batteries, the lighting battery when properly equipped can be used for the ignition. With such a system it is good practice for the wiring to be such that the headlights can be switched off and the side lights be left burning while running in the city, and vice versa when running in the country.

In the generator and storage battery systems the battery floats on the line and furnishes the energy for the lights when the car is at a standstill or running at a speed so low that the voltage would otherwise be too low to light up the lamps. When the generator voltage falls below that of the battery the generator is disconnected by a disconnecting switch, making it impossible for the battery to discharge and run the generator as a motor.

One of the most successful types, by virtue of an ingenious yet simple scheme of winding, automatically regulates the current irrespective of speed variations. That is, when the lamps are turned on, a higher current output from the generator itself is obtained. When the lamps are switched off, the current falls off to a safe charging value for the batteries. The field is compound wound, and is surrounded by a permanent magnet to prevent a reversal of polarity. Provision can be made for ignition in conjunction with the lighting system. The generator can be driven by gear, silent chain or belt drive.

In the magneto system a storage battery must be used as an auxilliary, with a relay or hand operated switch to throw it on when the car is not running. With any generating or battery system it is necessary to have the smallest possible length of wire between the source of energy and the lights, since with so low a voltage a small drop means a big per cent. of the original voltage.

Any argument which applies to the lighting of automobiles by electricity applies equally well to motor boats and motor cycles. For the motor cycle the limited space gives the electric headlight an advantage over any other means of illumination. A $3'' \times 3'' \times 6''$, 2 volt, 20 ampere hour battery is generally used, and can be placed in the tool box.

Bulbs

The shape of the bulb of the regular types is designated by a letter, and the diameter, in eighths of an inch, by a figure following this letter; "P" for pear shape, "G" for round and "T" for tubular. For example a G-12 bulb is a

round bulb $1\frac{1}{2}''$ in diameter; a G-6 bulb is a round bulb $\frac{3}{4}''$ in diameter. Besides the regular types there are various shaped bulbs for decorative purposes and many other special lamps.

Bases

The standard bases for miniature lamps are the miniature screw base and candelabra screw base. The former is $\frac{3}{8}''$ in diameter and $\frac{7}{16}''$ long, with 14 threads to the inch, and the latter is $\frac{7}{16}''$ in diameter and $\frac{19}{32}''$ long, with 10 threads to the inch. The Bayonet Candelabra base is furnished for special service, such as automobiles, etc.

Sockets and Shades

A large line of shades of all colors is supplied for Miniature lamps, which add materially to their decorative qualities. Since shade holders for Miniature Candelabra sockets are not interchangeable, the style wanted should always be specified.

Train Lighting

It is needless to dwell upon the advantages of electrically lighted trains. Along with the modern steel coaches the further safety of electrical equipment is essential. Other than immunity from fire, there are added advantages both in convenience and in appearance. An electrical equipment permits the use of berth-lights and any desired distribution of units. The train so equipped with means for making travelling pleasant has in itself a definite advertising value. The Drawn Wire filament of the Mazda lamp, with its low energy consumption, its strength, and its adaptability to any situation, has solved the problem of scientific and economical train lighting.

The round bulb has been generally adopted as a standard for train lighting, as this type harmonizes much better with the general appearance of the car. 10, 15, 20 and 25 watt Mazda lamps are supplied in the G-18½ round bulbs, 2-5/16″ in diameter, and a 50 watt lamp in the G-30 round bulb, 3-¾″ in diameter. 10, 15, 20 and 25 watt lamps are also supplied in either the S-19 bulb, 2-3/8″ in diameter, or the S-17 bulb, 2-1/8″ in diameter. A 40 watt lamp is supplied in the S-19 bulb, 2-3/8″ in diameter, and a 50 watt lamp in the S-21 bulb, 2-5/8″ in diameter. These lamps are all furnished in two ranges, 25 to 34 volts and 50 to 65 volts. At present the 15 watt Mazda lamp in the G-18-1/2 bulb is generally used for berth lights, although the Gem lamp in a G-12 bulb, 1-1/2″ in diameter is sometimes used in coaches having old fixtures.

The Edison Train Lighting lamps are furnished with the medium screw base, except the Gem Berth Light, which is fitted with the Candelabra screw base.

Three general systems for supplying current

are used in train lighting. They are known as the "Head-End," "Straight Storage" and "Axle Generator" systems.

Head-End System

The Head-end system consists of a complete power plant, including a steam turbine-driven generator, a storage battery and a switchboard. The generating set is located either in the baggage car at the front of the train, or is mounted on the locomotive. When installed in the baggage car, steam is supplied from the locomotive either by a direct steam line or through the heating system.

The battery supplies current for the lights when the locomotive is disconnected from the train. It also supplies a part of the current when the load is greater than the capacity of the generator set. An additional battery is often installed in the rear car so that the rear half of the train will not be in darkness in case an extra car is placed in the middle of the train.

The Head-end system is used principally on "solid trains" where the cars are kept together throughout the entire trip.

Straight Storage System

In the Straight Storage system, storage batteries are used alone, one for each car. The cells are usually arranged in two sets of 16 each, which, when connected in series, give a voltage range of 57 to 65 volts, and when in multiple, a voltage range of 28 to 34 volts.

With the straight storage system, facilities for charging the batteries must be provided at the terminals.

Axle Generator System

The Axle Generator system consists of a small generator on each car, usually mounted on the truck frame, and driven from the car axle by a belt or chain. A storage battery is also provided for each car to furnish light when the car is not moving.

In order to prevent the battery from feeding back into the generator when the train is running at low speed, an automatic switch is used which disconnects the generator from the battery when the voltage of the generator is lower than that of the battery. This automatic switch also connects the generator to the battery when the voltage of the generator rises to the normal value. It is usually designed to connect in at train speeds of about 15 miles per hour.

To prevent the generator voltage from rising to an excessive value when the train is running at speeds higher than the "cutting-in" speed, a regulating device is used, consisting of a variable resistance inserted in the field of the generator, or a separately driven generator which

either bucks or boosts the main generator field.

An automatic device is also used to maintain the polarity of the wires from the generator to the battery when the direction of the car's motion is reversed.

Automatic variable resistances are used in series with the lamp circuits to maintain a more nearly constant voltage at the lamps. This reduces the lamp renewal cost by preventing excessive voltage on the lamps, and furnishes steady illumination.

Sign Lighting

Electric Sign Lighting is simply a part of the immense advertising field, and should be so considered. It should be borne in mind by the merchant, the sign maker and the central station that an electric sign is first, last and always an advertisement, and its ultimate success depends to what degree these facts are borne in mind.

Some merchants seem to have the impression that an electric sign is expensive advertising. Nothing is further from the truth. When considered strictly as an advertisement and figured on a per capita basis, electrical advertising is the cheapest, as well as the most effectual method of reaching the public. National advertisers are beginning to realize this and are erecting large spectacular displays in the principal cities of this country.

As compared with other methods of advertising the electric sign has the following advantages:

It works both night and day.
It has the virtue of continual repetition.
It costs less per capita than any other method of advertising.
It is brief, concise and right to the point.
The impression produced is a lasting one.
No turning of pages.
No irrelevant matter.
Costs nothing to read it.
Read by all classes of people.

Kindly bear in mind that it is not the object of the electric sign to supplant either newspaper or magazine advertising, as these branches of advertising are closely related, and in order to get the best results all should be used in conjunction with each other. The story is told in detail in magazines and newspapers, and the spectacular electric sign follows with its flashing presentation of the trademark or name of the merchant.

To produce the best results, signs should be carefully constructed, for good material and workmanship are very essential. The sign should be erected in such a way as not only to

9. Cost of Operating Signs containing various numbers of 5 Watt Lamps for 2000 Hours service, including cost of Power and Renewals.

No. of Lamps		100	200	300	400	500	600	700	800	900	1000	1100	1200
Cost of Renewals		$30	$60	$90	$120	$150	$180	$210	$240	$270	$300	$330	$360
			Total Cost (Power and Renewals) for 2000 Hours Burning										
	1	$ 41	$ 82	$ 123	$ 164	$ 205	$ 246	$ 287	$ 328	$ 369	$ 410	$ 451	$ 492
Cost of	2	52	104	156	208	260	312	364	416	468	520	572	624
	3	63	126	189	252	315	378	441	504	567	630	693	750
Power	4	74	148	222	296	370	444	518	592	666	740	814	888
	5	85	170	255	340	425	510	595	680	765	850	935	1020
per Kw-hr	6	96	192	288	384	480	576	672	768	864	960	1056	1152
	7	107	214	321	428	535	642	749	856	963	1070	1177	1284
in	8	118	236	354	472	590	708	826	944	1062	1180	1298	1416
	9	129	258	387	516	645	774	903	1032	1161	1290	1419	1548
Cents	10	140	280	420	560	700	840	980	1120	1260	1400	1540	1680
	11	151	302	453	604	755	906	1057	1208	1359	1510	1661	1812

The above table is based on the list price of clear lamps, June, 1912.

To obtain the cost of lighting at any charge per kw-hr for any lamp at a discounted price—subtract the discounted price from the renewal cost in this table and subtract the remainder thus obtained from the numbers in the corresponding column.

An allowance is made in this table for a loss of .5 watts per lamp to take care of the wattage consumption in the transformers and in the wiring.

appear safe but also to be safe. The signs built by the successful companies are designed on this principle, having a higher factor of safety than would appear to be necessary, so that a failure of any part of the sign is practically impossible.

Sign Lamps

The Mazda Sign lamp situation has been wonderfully improved by the addition of two new lamps. The General Electric Company is now manufacturing 10 watt, 100 to 130 volt, and 5 watt, 50 to 65 volt Mazda Sign lamps. The addition of these two new lamps makes the sign lamp schedule complete, and there is no logical reason why any merchant should continue to use the inefficient carbon lamps. The use of the Mazda lamps insures more light and better light for less expense than the Carbon lamps. See Table 10 for a complete list of Mazda Sign lamps.

10. TECHNICAL DATA COVERING THE COMPLETE SCHEDULE OF MAZDA SIGN LAMPS.

Voltage	Rated Watts	Rated W. P. C.	Mean Horiz. C.P.	Average Total Life	Std. Pkg. Qty.	Bulb Style	Bulb Diam.	Length over all	Base
10 -13	2-½	1.33	1.8	2000	100	S-14	1¾	3¼	Std.
10 -13	5	1.33	3.8	200	100	S-14	1¾	3¼	Std.
10 -13	5	1.33	3.8	2000	100	P-12½	1 9/1	3¼	Cand.
50 -65	5	1.5	3.3	2000	100	S-14	1¾	3¼	Std.
100-130	10	1.5	6.7	2000	100	S-14	1¾	3¼	Std.

As the 10-13 volt sign lamps are made in 1/2 volt steps, the voltage of the lamps to use would be the nearest 1/2 volt obtained by dividing the circuit voltage by 10. As an example, suppose the circuit voltage in a particular case is 113; by dividing 113 by 10 we get 11.3, and hence we should use 11.5 volt lamps in this case. With the 50-65 volt and 100-130 volt lamps, the voltage to be ordered should be obtained by testing the voltage directly at the lamp sockets. In case of voltage fluctuation the maximum value should be used.

It has been demonstrated time and time again that when operated properly Mazda Sign lamps give satisfactory results. In order to avoid misunderstanding in the future each method of wiring will be taken up separately.

Mazda Sign wiring, as experienced by the Central Station and merchant, may be divided into two broad classes:

First, Cities having direct current.

Second, Cities having alternating current.

On the opposite page is given in tabulated form the methods of wiring and types of lamps to use on direct current.

For Cities Having Direct Current

Size of Sign	Voltage	Wattage	Method of Wiring	Lamp to Order
Under 100	10-13	2.5, 5,	10 in series	Series
Over 100	10-13	2.5, 5,	Multiple series	Series
Any number	50-65	5	2 in series	Series
" "	100-130	10	Multiple	Multiple

10 in Series

It will be noted in the above table that the series method of wiring with 10 lamps in series (Fig. 16) is only recommended where the sign con tains less than 100 lamps. Under no condition should a sign containing, say 300 or 400 lamps be wired in straight series, as unsatisfactory performance will probably result. It is recommended that in every case 10 lamps be wired in each series, the voltages of the lamp being one-tenth of the circuit voltage. As the same current flows through all the lamps in each series, it is necessary that the lamps *be selected for amperes*. This is done by the lamp manufacturers, and all lamps so selected have an additional label reading SERIES BURNING. **Do not operate lamps of different manufacture in the same series,** because the different manufacturers select their series lamps according to different schedules, and hence by mixing them unsatisfactory performance will result.

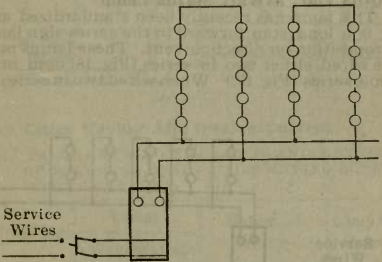


Fig. 16

Multiple Series

When a sign contains more than 100 lamps, and it has been decided to use 10-13 volt lamps, it is recommended that they be wired in multiple series (Fig. 17) with 10 multiple banks con-

nected in series. If it is decided to wire less than 100 lamps in this manner it is recommended that enough resistance be inserted to make the total resistance equal to that of 100 lamps. As series lamps are selected for volts and amperes, it is evident that they should be used for this class of service and the order should so specify.

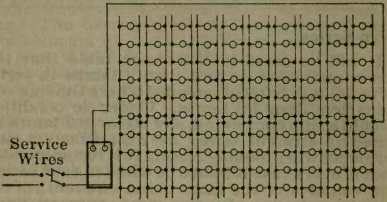


Fig. 17

When the lamps are so wired that the failure of one lamp in a multiple bank causes the remaining lamps to be operated at an excess voltage, it is suggested that **all burn outs be promptly replaced.** Therefore, when a sign is wired in this manner it should be easily accessible so that any lamp which has failed can be replaced promptly and conveniently.

50-65 Volt, 5-Watt Mazda Lamp

This lamp has recently been standardized and it is a long step forward in the series sign lamp proposition on direct current. These lamps may be wired, either two in series (Fig. 18) or in multiple series (Fig. 19.) When wired two in series, it

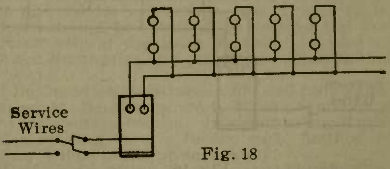


Fig. 18

is suggested, that the lamps be staggered so that the failure of one lamp will not throw out two adjacent lamps. In the case of a double face sign it is recommended that the lamps on each side be wired in multiple and the two sides be connected in series. In this way we get a condition of operation which is practically similar to

straight multiple, as when approximately 50 amps are used on a sign, the failure of one lamp will not unbalance the circuit to any appreciable extent.

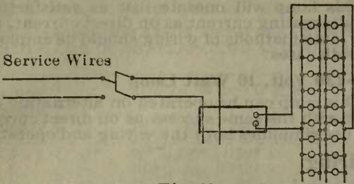


Fig. 19

100-130 Volt, 10 Watt, Mazda Lamp

This new sign lamp makes it possible to wire the signs in straight multiple, (Fig. 20) this being the most simple and satisfactory method of wiring in practice. This lamp makes it possible to eliminate transformer expense, and thus helps to offset the slightly higher renewal cost of the lamps. It is possible to replace any existing 30-watt or 20-watt Carbon lamp by this lamp, without any rewiring, to show a material saving to the customer, and at the same time greatly improve the appearance of his sign.

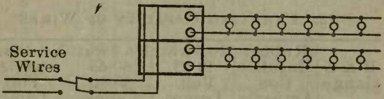


Fig. 20

For Cities Having Alternating Current

11. TABLE SHOWING THE LAMPS AND METHODS OF WIRING TO USE IN CITIES HAVING ALTERNATING CURRENT.

Size of Sign	Lamps		Method of Wiring	Lamp to Order
	Voltage	Wattage		
Any Size	10 –13	2.5, 5	Multiple, trans.	Multiple
Any Size	50 –65	5	two in series	Series
Any Size	100–130	10	Multiple	Multiple

10-13 Volt Lamps

Since the multiple method (Fig. 20) of operating lamps is always the best, it is recommended that a transformer be used whenever

alternating current is available. The transformer expense is justified since the best possible performance is secured by its use.

50-65 Volt, 5 Watt Lamp

This lamp will operate just as satisfactorily on alternating current as on direct current, and the same methods of wiring should be employed in both cases.

100-130 Volt, 10 Watt Lamp

This lamp can be operated on alternating current with the same success as on direct current. Its use simplifies both the wiring and operation.

Wiring

For low voltage Mazda Sign lamps the wiring must be such that the voltage drop does not exceed a certain definite amount, and that the Fire Underwriters' Rules are not violated. According to the specifications of the National Board of Fire Underwriters not more than 1320 watts shall be dependent upon the final cut-out. In some cases, however, the municipal rules allow only 660 watts, and this ruling must be observed and the wiring governed accordingly. Below is a table which shows the carrying capacity of wires as approved by the National Board of Fire Underwriters. It is seen from this Table that with low voltage Mazda lamps the carrying capacity of the wires is the governing feature.

12. Carrying Capacity of Wires

B & S Gauge	Rubber Insulation Amperes	No.5 watt 10-13 Volt Lamps	No 5 watt 50-65 Volt Lamps	No. 10 watt 100-130 Volt Lamps
14	12	27	127	127
12	17	38	181	‡
10	24	54	256	......
8	33	75	‡	......
6	46	104	......	......
5	54	122	......	......
4	65	147	......	......
3	76	172	......	......
2	90	204	......	......
1	107	242	......	......
0	127	‡	......	......

‡ Exceeds the 1320 watts as allowed by National Board of Fire Underwriters.

With the 10-13 volt lamps it is essential that the voltage drop in all cases be less than ½ volt. Table 13 gives the number of lamps which can be used on the four different sizes of wire when the

lamps are placed at various intervals in order that the drop may be less than ½ volt. Table 14 gives the maximum number of 5 watt, 10-13 volt lamps wired in multiple that can be supplied with feeders having the size and length given in the table, with a drop of not exceeding .2 volts.

13. SHOWING RELATION BETWEEN NUMBER OF LAMPS, SIZE OF WIRE, SPACING AND VOLTAGE DROP.

Spacing of Lamps in Inches	Size of Wire (B & S) 14	12	10	8	
3	64*	92*	125*	159*	Number of Lamps
6	55	70	88	112	
8	47	60	75	97	
10	42	54	68	86	
12	38	49	62	79	
16	33	42	54	68	
20	29	38	48	61	

14. NUMBER OF LAMPS, SIZE AND LENGTH OF FEEDERS.

Combined length of pair of feeders.	Size of Feeder (B & S) 10	8	6	4	2	
3	64*	92*	130*	184*	262*	Number of Lamps
4	50	77	125	184*	262*	
5	40	62	100	158	254	
6	33	53	84	135	210	
8	25	40	63	101	160	
10	20	31	50	79	127	
15	13	21	33	53	85	
20	10	15	25	39	63	
30	7	10	17	26	42	

* This limit imposed in order not to exceed the safe carrying capacity of weather-proof wire.

With the 50-65 volt, 5 watt, and 100-130 volt, 10 watt lamps, since the amperage is very small the governing feature will be the limit of 1320 watts imposed by the National Board of Fire Underwriters.

Sign Lighting Transformers.

The General Electric Company has developed a complete line of transformers for reducing the circuit voltage to that of Mazda sign lamps. The transformation ratio is 10 to 1 and 20 to 1, and consequently with a primary voltage averaging 110, 11 volt lamps should be used and with primary voltage of 120, 12 volt lamps should be used, etc. These transformers are made in four standard sizes, as shown in Table 15.

As the secondary can be connected for either two or three wire service, the transformers can, therefore, be applied to any sign without necessitating a change in wiring.

15. G. E. Sign Lighting Transformers.

Capacity Watts	Capacity 5-watt Lamp	Wall Space Inches	Depth Inches	Net Weight Pounds	Catalog Number
250	50	7 x 6¼	5½	30	76676
500	100	8 x 8	7¼	45	76678
1000	200	9 x 9	9	70	76680
2000	400	10½ x 10	10	100	76683

Flashers.

The flasher has three advantages; it gives movement, which attracts attention, enables one to secure spectacular effects, and reduces the amount of current necessary to operate a given sign. To prevent arcing and also because most flashers are designed to operate on 110 volts, it is recommended whenever possible that the flasher be placed on the service side of the transformer. However the simple on and off flashing sign is the only type that can be so arranged because the several circuits of a complicated sign must be brought together at the flasher and cannot be united in the transformer on the way.

In Table 16 we have given the various kinds of flashing effects with the corresponding possible methods of wiring on either direct or alternating current. The type of lamp which can be used in order to produce these flashing effects is shown in the last column.

16. Table showing the possible systems of wiring and lamps to use for various flashing effects:

Flashing Effect	Current	Wiring	Lamps
Steady Burning, On and Off, One line at a time	A.C. or D.C.	Mult.	110 V. Mazda
		Mult. Series	10 V. "
		Ten in series	10 V. "
		Two " "	55 V. "
One line at a time	A.C.	Mult. with Trans.	10 V. "

Flashing Effect	Current	Wiring	Lamps
Script, Spelling, Fountain	D.C. or A.C.	Multiple	110 V. Mazda
Fountain, Rat Chaser, Falling Water, Lightning	A.C.	Multiple with Trans.	10 V. Mazda

In order to estimate approximately the number of lamps which will be required for any sign, the following table is given which shows the average number of sockets for different sizes of letters

Average Number Sockets for Different Size Letters

12″	8
14″	8½
16″	8½
24″	10½
36″	13½
48″	17
60″	20
72″	24
84″	27
96″	32
108″	36
120″	39

In Special designs a space of 5″ between centers of sockets can be used for estimating the number of receptacles.

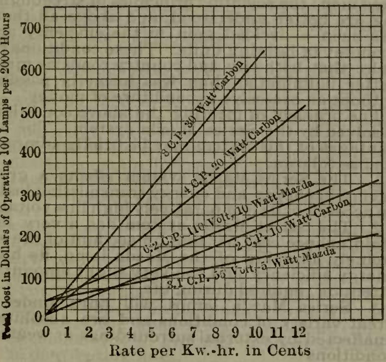


Fig. 21

Fig. 21 shows the approx. total operating costs of corresponding carbon and Mazda sign lamps. The decided economy of the Mazda lamps is clearly shown. These curves are based on standard package prices in effect June 1, 1912.

Street Lighting

During the last few years remarkable advances have been made in the standard of illumination required for street lighting. The introduction of Mazda Street Lighting Lamps has undoubtedly been one of the most noteworthy advances along this line. With the increased economy and effectiveness insured by their use, the benefits of electric street lighting are now practically applicable to all classes of service in either large or small cities. They have for the first time made it commercially possible to operate satisfactorily both arc and incandescent units in series on the same circuit, thus providing the most flexible and efficient system of street lighting ever devised. This system allows a wide selection of candle power sizes so that by distributing both Mazda and Arc Lamps where they will do their best work, a very effective and economical arrangement can be obtained, which eliminates much of the dissatisfaction inherent in former systems of lighting. Moreover the conditions of the present day differ greatly from those of the past; greater crowds are on the street in the evening; high speed vehicles are more generally used; the commercial value of good lighting is realized by a larger per cent. of business men; the scientific principles of street lighting are better understood, and above all there has been a decided gain in the efficiency and economy of lighting units. These conditions require that both city and country roads be much better illuminated than was formerly possible without an excessive expenditure of money.

The problem of meeting the above conditions is solved by the Series Mazda system. The advantages of this system may be briefly summarized as follows:

1. The Series Mazda system effects a great saving in copper and energy transmission losses on account of its comparatively high line voltage.
2. The Series Mazda system has a very low maintenance cost per unit on account of the extremely long life of the Mazda lamp, its high energy efficiency and the very slight amount of attention required during life.
3. Series Mazda lamps will burn under a great variety of conditions and are absolutely unaffected by external surroundings or weather conditions
4. Series Mazda lamps are made for many different current strengths, thus allowing the selection of that value of current which is most economical under the local generating and transmission conditions.
5. Series Mazda lamps are made in many different sizes, and, as all operate at a high efficiency, that size unit can be selected which will give the desired amount of light most economic-

ally, or where the appropriations for street lighting increase slowly, the standard of illumination can be increased accordingly.

6. The Series Mazda system allows several different size units to be connected to the same circuit, and an easy method of changing either temporarily or permanently the amount of light at any spot.

7. Series Mazda lamps have a low intrinsic brilliancy and thus reduce glare to as low a value as is compatible with economy.

8. A Series Mazda system permits standardization of equipment, interchangeability of parts, and lighting of an entire city from the same or similar circuits.

9. The Series Mazda system offers a simplicity and ease of operation and control unsurpassed by any other system.

10. The Series Mazda system utilizes to the highest degree all the light rays from the lamp units, even when the streets are narrow, crooked, hilly or lined with shade trees.

11. The Series Mazda lamps when equipped with radial wave reflectors increase by about 25% the maximum intensity of light at the angles near the horizontal, thus throwing the greatest amount of light out to the distant points.

12. The Series Mazda lamps have a color value very near to that of daylight, thus giving objects their normal appearance.

Equipment

With a Series Mazda system all the lamps are designed for the same current flow, and therefore some method is necessary for holding the current in the circuit constant. For this purpose a transformer has been especially designed by the General Electric Company which changes the nearly constant impressed voltage to constant secondary current. This transformer has been so well designed that it holds the secondary current within 1/10 of an ampere of its normal value from no load to full load, even with a 5% variation in impressed voltage. This transformer gives a closer regulation, higher efficiency and a better power factor than any other constant current regulator, and at the same time by keeping the primary and secondary circuits separate, protects the generating equipment from any accidents due to grounds or short circuits on the distributing lines.

The series socket and cut-out is very necessary for the successful operation of a series system, and is designed for two special purposes; first, to short-circuit the lamp automatically when the filament fails, and second, to permit the removal of the lamp from a live circuit without interrupting the service.

For general purposes all streets may be divided into four classes:

1. Principal business streets.
2. Important cross streets and boulevards.
3. Residence streets.
4. Outlying districts.

In every one of the above divisions the Mazda lamp can be used so as to economically give an abundance of light, and in most cases at a cost less than that for any other type of illuminant. Where a high intensity of light is desired, units of about 200 or 350 candle-power should be used, but in the majority of cases a smaller size lamp will be found more suitable. With the smaller lamps, spaced more frequently, more uniform illumination is obtained, less glare is experienced and the general lighting effect is much better. If we have a certain minimum intensity on the street and desire to keep this value constant, but to double the distance between lamps, then we find that the new light unit must be at least four times as powerful as the old ones; conversely, if we decrease by half the distance between lamps and keep the same minimum illumination our new light sources need be only one-fourth as powerful as the original lamps. It will therefore be seen that the saving in energy increases very rapidly as we decrease the size of the lamps and their distance apart, while at the same time maintaining the same minimum intensity of light. Consequently the Series Mazda lamps are the most economical illuminant for streets where a uniform low intensity of light is desired.

Upon the principal business streets the illumination should be of a character, both in brightness and general appearance, to bring credit to the city. For this class of street lighting the Mazda lamp, whether in multiple or series, has been a popular illuminant. The best results have been obtained from posts placed opposite one another on each side of the street, at a distance apart slightly greater than the width of the street. Five lamps per post are commonly used, enclosed in a diffusing globe, and of a size to give approximately 10 watts per running foot of street. It is also the practice to use combination trolley lighting poles, where an agreement can be reached between the trolley and lighting company. In other towns where the ornamental feature is not desired, 350 C. P. Mazda lamps should be used, and equipped with a 24″ Radial Wave reflector. These lamps should be placed from 20 to 25 feet above the ground, and about 100 feet apart.

Upon the important cross streets and boulevards either one-light ornamental standards can be used, placed at the sides of the streets, or lamps suspended from brackets, and equipped with Radial Wave reflectors. In each case the lamp should be placed at the side of the street so as to reduce the glare, for the foliage often

requires a low suspension of the lamp. Where the foliage does not interfere with the distribution of the light the lamp should be placed from 15 to 20 feet above the ground. The lamps commonly used are the 60 and 100 C. P.

Upon the residence streets the lamp is usually suspended at the side, as it is less expensive than the center suspension, and gives sufficient illumination over all the street, except where same is unusually wide. The most common equipment consists of either 40, 60 or 80 C. P. lamps, equipped with 20″ Radial Wave reflectors, and placed from 15 to 18 feet above the ground.

In the outlying districts the character of the lighting depends on the amount of money available for this work. The 32 and 40 C. P. lamps are generally used and placed about 15 feet above the ground. Staggered placing of units is seldom advisable in street lighting, as it makes the outline of the road less distinct, especially where there are curves.

Rating of Lamps

Owing to recent improvements in lamp manufacture it is now possible to supply series lamps for a definite amperage rather than for an ampere range, as has been the practice heretofore.

This improvement has been long striven for, as it permits the central stations to use one current value on their series lines and thus make all their apparatus interchangeable. It is to the advantage of the central stations, therefore, that in all new installations they adopt a standard ampere value, preferable 6.6, and also that they change their present lines to the nearest standard current value.

The standard amperages are as follows:

Ampere Range of Lamps Used in the Past	Standard Ampere Lamps to be Used in Future
3.0 to 3.8	3.5
3.8 to 4.3	4.0
5.1 to 5.9	5.5
6.1 to 6.9	6.6
7.0 to 8.0	7.5

Mill Lighting

In mill work the quality of illumination plays an important part in the efficiency of production. In a well lighted mill the actual operating hours may be increased, thereby increasing the output, while the fixed charges remain the same. Spoilage has proven to be the chief obstacle to economical production in mill work. Census experts claim that 25% of the total spoilage can be avoided by good illumination. The employee, considered as a unit with his machine, works at least 2% more efficiently under good than under

poor illumination. Furthermore, the employee of several years' service, will, by virtue of his long training, be highly efficient, provided his eyesight has not been injured by working under poor illumination. An investment in a good lighting system is a good insurance against liability for accident. This is borne out by statistics, which show that the greatest number of industrial accidents occur in those months which average the greatest number of hours of darkness and gloom.

The effect of well lighted surroundings upon the employee is also a consideration not to be neglected. No far sighted mill man would cut off his heat supply during the winter months to reduce his operating expense. The same should be said about his illumination, as a man whose mill is well illuminated removes by several degrees the likelihood of labor disturbances.

The General Electric Company has a complete line of information covering any class of lighting service. A request for advice on any phase of lighting service will secure a Bulletin giving a review of conditions to be met with, and recommendations for securing the best results. Recommendations for the lighting of Textile Mills are given below, and in the table beginning on page 23 will be found the intensities recommended for various other classes of lighting service.

Recommendations

Cotton Processes

OPENERS.
One 40 watt Mazda lamp with extensive Holophane D'Olier reflector over each end of machine.

PICKERS.
Same as Openers.

CARDING.
One 40 watt Mazda lamp with extensive steel reflector, per machine staggered.

DRAWING FRAME.
One 40 watt Mazda lamp with extensive D'Olier reflector, spaced 8 feet.

ROVING FRAMES.
Two 40 watt Mazda lamps with extensive reflectors in aisle, spaced 7′ to 10′.

RING SPINNING.
Two 60 watt Mazda lamps with extensive reflectors in aisle. spaced every 100 spindles on each side of alley.

TWISTING.
Same as Ring Spinning.

SPOOLERS.
Two 60 watt Mazda lamps with extensive reflectors in aisle, spaced 7′ to 10′.

Warping.
One 60 watt Mazda lamp with extensive reflector over beam.
One 60 watt Mazda lamp with intensive reflector over or inside rack. General illuminants when warpers are movable.

Slasher.
One 40 watt Mazda lamp with extensive reflector at each end of the machine.

Drawing In.
General illumination in portion of mill for drawing in furnished by 40 watt Mazda lamps, with extensive reflectors, spaced 10′ centers. Supplemented by special lights on each stand.

Weaving.
Looms for light colored goods up to 42″, one 60 watt Mazda lamp with extensive reflector, at center of square formed by four machines. Looms for 54–72 inch goods, one 60 watt Mazda lamp with extensive reflector at each end of machine in weaver's alley.

Inspecting.
One 60 watt Mazda lamp with intensive reflector over each table.

Packing and Shipping.
General illumination, 100 watt Mazda lamp with extensive reflector hung 12 feet above floor, spaced about 15 to 18 foot centers.

Silk Processes

Winding Frames and Throwing Frames.
Three 60 watt Mazda lamps with extensive reflectors, placed in aisle, spaced 7′ to 10′.

Quilling.
Two 60 watt Mazda lamps with extensive reflectors in aisle, spaced 5′ to 10′.

Warping.
One 60 watt Mazda lamp with extensive reflector over creel.
One 60 watt Mazda lamp with intensive reflector over reed.
One 60 watt Mazda lamp with extensive reflector over reel.

Weaving.
One 60 watt Mazda lamp with intensive reflector over lay of loom.
One 40 watt Mazda lamp with extensive reflector in rear alley.

Finishing.
One 60 watt Mazda lamp with intensive reflector over each table.

Packing and Shipping.
100 watt Mazda lamp with extensive reflector, 12 feet high, spaced 15′ to 18′.

PICKING TABLE.
One 40 watt Mazda lamp with intensive reflector over each table. If tables are placed back to back, one 60 watt Mazda lamp with extensive reflector.

WASHING.
General illumination, 100 watt Mazda lamps with extensive reflectors, 12′ above floor, spaced 10′ to 12′.

COMBING.
General illumination, 100 watt Mazda lamps with extensive reflectors, 10 to 12 feet high with 10 to 12 foot centers.

CARDING.
One 40 watt Mazda lamp with extensive reflector per machine staggered.

TWISTING.
40 watt Mazda lamps with extensive reflectors, 7′ above floor in aisle, 7′ to 10′ centers.

DYE HOUSES.
Illumination can be greatly improved if ventilating fans are used to draw off steam. Place one 100 watt Mazda lamp with extensive reflector between every other tank. Raw stock dyeing machine, one 60 watt Mazda lamp with extensive reflector in front of each machine.
Skein and slubbing dyeing machines, one 60 watt Mazda lamp with extensive reflector in front of each machine.

DRAWING IN.
General illumination in portion of mill devoted to drawing, in 60 watt Mazda lamps with extensive reflectors spaced 8′ centers.

WARPING.
60 watt Mazda lamp with extensive reflector over reel. 60 watt Mazda lamp with intensive reflector over reed.

WEAVING.
One 60 watt Mazda lamp with intensive reflector over lay with 36″ goods.
Two 40 watt Mazda lamps with intensive reflectors over looms weaving 54″ goods.
One 40 watt Mazda lamp with extensive reflector in rear alley. (If black cloth, use 100 watt Mazda lamp for 36″, and two 60 watt for 54″ goods).

PERCHING.
One 100 watt Mazda lamp with intensive reflector over each perching frame. If perching frames are portable, by general illumination with 150 watt Mazda lamps with extensive reflectors, 10′ to 12′ above floor, spaced

12′ to 15′ centers; if dark cloth is perched, 250 watt Mazda lamps, 15′ to 18′ centers.

PACKING AND SHIPPING.
Same as above.

Knitting

KNITTING—RIB, TOP, SHIRT BODY, AUTOMATIC SEAMLESS AND COLOR STRIPER.
Machines generally placed in groups, one 60 watt Mazda lamp with extensive reflector to every four machines.

FLAT KNITTERS.
Place 60 watt Mazda lamps with extensive reflectors in aisle, spaced 6′ to 8′ centers.

LOOPING AND SEAMING MACHINES. FINISHING MACHINES.
One 25 watt Mazda lamp with anchored reflector, hung 12″ above table and 18″ from head of machine.

NAPPER MACHINES.
One 40 watt Mazda lamp with extensive reflector over the front roll.

General Information on Incandescent Lamps

History of the Incandescent Lamp

The first commercial incandescent lamp was introduced by Thomas A. Edison in 1879. The filament was horseshoe shaped and was made of carbonized paper. The essential parts of the lamp were the same as those of the lamp of the present day. The efficiency at which the lamp operated was about 7 watts per candle. Later the efficiency was increased to 5.8 watts per candle by the adoption of a carbonized strip of bamboo. This increased the total life of the lamp, yet the candle-power declined approximately 20% in the first 100 hours. Further improvement in 1881 increased the efficiency to 4.6 watts per candle. The present carbon filament is made by dissolving absorbent cotton, forming a thick viscous solution, which is forced under pressure through a die, forming a long thread-like filament, which is then carbonized. The efficiency of the present carbon filament is approximately 3.1 watts per candle.

The next important step in the development of the incandescent lamp was the "metallization" of the Carbon filament. This was placed on the market as the Gem lamp by the General Electric Company. The Gem filament is produced by heating the ordinary treated Carbon filament in an electric furnace to a very high temperature. The cold resistance of the filament is considerably reduced by this heating, and the temperature coefficient is changed from negative to positive. This improvement is shown in the resistance curves on page 73. The refractoriness of the filament is increased sufficiently to permit its operating at a temperature some 200° higher than the carbon filament for the same deterioration. The most important advantage is the increase in efficiency, the Gem lamp operating at 2.5 watts per candle as compared with 3.1 watts per candle for the Carbon.

The Tantalum lamp was placed on the market in 1906. It had an added efficiency over the Gem, operating at 2 watts per candle. As the Tantalum lamp gave rather unsatisfactory service on alternating current it has given way to the more efficient Mazda lamp. The metal tungsten of the Mazda filament has a high melting point, and high vaporizing temperature. These qualities are essential to a good filament. The tungsten filament is also a poor radiator of heat, and accordingly operates more efficiently than the Carbon filament. The high efficiency of the

17. Comparison of the Qualities of the early (1881) Carbon Lamps and the present Carbon, Gem and Metal Filament Lamps.

SHOWING IMPROVEMENT IN THE LAMPS AND GAINS IN LIGHTING ECONOMY.

Description	Early Carbon Lamps—1881	Present Carbon Lamp—1912	Gem Filament Lamp—1912	Tungsten Pressed Filament Lamp—1908	Tungsten Drawn Wire Lamp—1912
Efficiency in W. P. C.	5.8 and 4.66	3.1	2.5	1.25	1.20
Voltage Range	50-120	10-275	100-130	100-125	10-250
Candle Power Range for Above voltage	10-20	2-50	16-100	20-200	2-500
Candle Power for 50 watts	8.63	16.15	20.0	40	41.6
Cost per Lamp: List Price	.65	.16	.20	1.50	.75
Cost per Lamp: For 1000 hours at list price	6.50	.228	.285	1.50	.75
Cost per 1000 Candle-hours of light: For pr. @ 10c. per kw-hr.	.892	.387	.294	.132	.126
Cost per 1000 Candle-hours of light: For renewals	1.158	.017	.016	.039	.018
Cost per 1000 Candle-hours of light: Total	2.050	.404	.310	.171	.144

Tungsten filament is further due to selective radiation as defined on page 2. The average efficiency of the pressed filament Mazda lamp was about 1.23 watts per candle, with a life of 1000 hours.

Pure tungsten metal has a very bright steel gray appearance, is very heavy, having a specific gravity of 19 12, and until recently was produced only in a brittle form. Recently improved methods of manufacturing tungsten into wire made it possible to produce the drawn wire Mazda lamp. The possibility of producing tungsten wire in great lengths has permitted a change in the construction of the lamp, by which a continuous filament is employed, instead of welding four or five filament loops together, as was done in the past. This new construction furnishes a lamp that is many times stronger than the pressed filament. This lamp operates at an average efficiency of 1.15 watts per candle with a life of 1000 hours.

The temperature of the Mazda filament reaches about 2300° Centigrade when operated at 1 watt per candle, and between 2100° and 2200° Centigrade when operated at 1.25 watts per candle. The filament has a high positive temperature coefficient so that a remarkably steady candle-power is obtained over a comparatively wide range of voltage. This is shown by the curves on page 71. Due to the high positive temperature coefficient the current density remains fairly constant insuring a uniform life.

Etching and Frosting

Etching

The process of etching lamps with names, letters, symbols, etc., is simple and inexpensive, but when done by the manufacturer will cause delay in shipment, as it specializes every order. The following instructions will enable customers to etch their own lamps, but it should be borne in mind that **the solution described will not give satisfactory results for frosting:**

Mix in a small lead or rubber cup a good grade of hydrofluoric acid, and crystalline ammonium carbonate until the acid is partly neutralized. This can be determined by a test; if too little of the carbonate is present, the etching is more of a transparent eating of the glass. To obtain clear cut letters or symbols, spread a little of the acid on a rubber pad with a tooth brush, or something similar, then spread the solution on the rubber stamp to be used, taking it from the pad with a brush. Ordinary blotting paper may be used to remove an excess of acid from the stamp. Now take a lamp and apply the rubber stamp to the part to be etched; this part of the lamp, previous to applying the stamp, should be heated

over an ordinary gas flame to a temperature that will render the lamp uncomfortable to the touch. A gas heater can be made of a perforated strip of sheet iron, arranged so that a tray of about 50 lamps can be placed on top of it with the base or tip of the lamp down, so as to heat the part to be etched. Be sure to return the etched lamps to the tray for reheating, as this gives better and quicker results.

Frosting

The term "frosted" lamp is used to describe a lamp with a frosted or etched bulb. Lamps may be permanently frosted by either sandblasting or acid etching, both processes giving results so similar that it is difficult to distinguish them. The acid method is used entirely in the frosting of Edison lamps. Although the mixing of the etching paste is comparatively simple, it is dangerous to handle and difficult to secure good results. For this reason it is not advisable for customers to do their own frosting.

The regular acid frosting is applied to Carbon, Gem and Miniature lamps of all classes. The "satin finish" frosting is used on regular multiple Mazda lamps. This is a more expensive operation, and is known as the German process. The solution is more or less a paste. Lamps are dipped in the paste, allowed to stand for sometime, and are then rinsed in water. The finish is smooth and satin like.

The principal styles of frosting are "bowl" frosting, "full" frosting and "bulls eye" frosting. In full frosting the entire bulb is frosted. In bowl frosting only the lower part or the bowl of the bulb is frosted. In bulls eye frosting the whole bulb is frosted, excepting a clear spot 2 inches in diameter. This type of frosting is sometimes used for stereopticon lamps.

Colored Lamps

Colored lamps can be supplied with bulbs made of either clear glass superficially colored or of natural colored glass. Superficially colored bulbs are bulbs which have had a dipping or coating of color applied to their exterior surfaces; their color is not weather proof. Natural colored bulbs are bulbs made from permanently colored glass; their color is weather proof.

The Best Lamp

The fallacy of the contention that the lowest price lamp is the best lamp lies in the assumption that a lamp's value is measured solely by its **first** cost, instead of by its ultimate cost. The first cost or price of a lamp is but a fraction of its **ultimate** or true cost, and completely ignores useful life, efficiency and cost of power, which are the most important factors of a lamp's cost.

To illustrate what a small percentage the first cost is of the ultimate cost and to set forth its incorrectness as a standard of lamp value let us assume that a carbon 50.0 watt, 2.97 w.p.c. lamp has a useful life of 700 hours, that its price is 16c, and that power costs 5c per kilowatt-hour:

Then $\frac{50 \times 700}{1000} = 35.00$ kilowatt-hours.

$35.00 \times .05 = \$1.75$ or cost of power

Price of lamp = .16

Therefore $1.91 equals **ultimate cost** of lamp

But $\frac{\text{Price of lamp}}{\text{Ultimate cost of lamp}} = \frac{.16}{1.91} = 0.084$

or 8.4 per cent.

Therefore while the first cost of the lamp at this life and efficiency is but 8.4 per cent. of its ultimate cost, the cost of power is 91 per cent. of its ultimate cost or nearly 11 times the price of the lamp.

Is the best lamp the lamp that lasts the longest or gives the **longest actual life?**

Let us consider:

The actual life of a lamp fails not only to comprise the important factors in lamp service of useful life, efficiency and cost of power, but ignores also the price of the lamp. Therefore, the actual life can be no criterion of a lamp's quality. Besides, experience demonstrates that long actual life is usually attained only at the expense of candle-power and efficiency. Lamps are made for the twofold purpose of giving light and life, not mere life alone, but **useful** life—life with candle power.

We therefore conclude that the best lamp is **not** the lamp that sells at the **lowest price** nor the lamp that **lasts the longest,** but is the lamp whose **ultimate cost** is the **lowest,** i.e., the cost of the lamp and the cost of power: or with equal price and economy the lamp that gives the longest **useful** life.

It is a fact demonstrated by test and practical experience that the Edison Gem and Mazda lamps surpass any and all makes in these desirable qualities. Compared with the products of other manufacturers they are, therefore, the cheapest lamps to use, although the prices are not always the lowest. That they alone are entitled to the distinction of "best" is shown by the claims made for other lamps that they are "as good as the 'Edison,' etc."

Characteristics of the Best Lamp

The best lamp has the following distinguishing features:

a—Absence of physical defects.
b—Correctness of rating.
c—Uniformity of performance.

d—Maintenance of candle-power.
e—Low ultimate cost of operation.

Edison lamps are carefully inspected after each step in their manufacture and are then subjected to a rigid final inspection before being sent out.

The lamps are carefully tested and selected to give the proper ratings.

It is not sufficient, however, that lamps **initially** meet all requirements; they must also, after installation, give **uniform** useful life, and during that life afford **uniform** candle-power and consume **uniform** watts or power; thereby rendering that uniform and definite lamp service which is so essential to good lighting. Uniform useful life makes possible the adoption of a simple and effective system of lamp renewals and also serves as an excellent index of the efficiency at which the lamps are operated. Uniform candle-power precludes unsatisfactory light contrasts and insures even illumination. Uniform watt or power consumption prevents complaints of excessive and uncertain meter bills: it eliminates the question of allowance to customers which is an undesirable source of friction and is the result of unsatisfactory and expensive lamp service; and it also insures stations which sell light by contract against loss due to excessive wattage or power consumption for which there is no pecuniary return.

An ideal lamp would be one that maintained its initial candle-power throughout its life. So then, other conditions being equal, the best lamp is the lamp that at a definite w.p.c. maintains its candle-power for the longest time, or the lamp that gives the best useful life.

In conclusion, it pays most decidedly to use carefully selected lamps, because the saving to the lamp user is worth many times the saving in first cost of a few cents which the careless and incompetent lamp manufacturer offers as an inducement to use his lamps. The amount paid for the extra wattage consumption of an inefficient lamp during its useful life is often six or seven times the first cost saving. It costs the careful and competent manufacturer much money to inspect his product rigidly and honestly, to test and select his lamps carefully, and to weed and cull out the imperfect ones. The user has the choice of wisely paying the full price for reliable results or of buying on price only, and of paying far more finally through failure, breakage and increased consumption of power.

Cleaning Mazda Lamps.

Where no regular provision is made for clean-

ing lamps, it is safe to say that the lighting would be increased 15% by the introduction of such service. With monthly cleaning the average loss of light due to dust will in most cases be only 2 or 3%. For a 100 watt unit burning 1000 hours, per year with energy at 10 cts. per kw-hr. the total operating cost will be about $12.00 and 15% of this is $1.80. The cost of cleaning this lamp monthly will amount to from 25 to 35 cts. per year, which means a saving in light of $1.45 to $1.55 per lamp per year by keeping the lamp clean.

Consider the case of a 250 watt Mazda lamp in an industrial plant where the units are used 4000 hrs. per year and energy costs 2 cts. per kw-hr. The total cost of operation is approximately $26 and a 15% saving amounts to $4.00. The units can be cleaned once a month for about 40 cts. per year, which is a saving in light of $3.60 per lamp per year.

These figures apply to average installations but in many instances the saving would be greater.

There are any number of schemes for cleaning lamps and reflectors. In offices, stores and places of such character, where glass reflectors are used, it will be found necessary to take the reflectors down for a thorough cleaning only once every three or four months, and when the lamps are renewed. A wet cloth used with a bristle brush is sufficient for a good cleaning until reflectors are taken down for washing. In cleaning lamps dry woolen or silk cloths should never be used, as the static electricity developed may cause the filament to break. Always use a cotton cloth or cotton waste. In textile mills and places where only a coating of dust settles on the lamps and reflectors a dry cloth is all that is necessary to put the lamps in good condition. In mills and shops where steel and enamel reflectors are used and where more or less grease accumulates on the reflector, a bunch of cotton waste and some gasolene is necessary to remove the dirt. In all cases it is seldom necessary to remove the reflectors in order to clean them.

In cleaning Mazda lamps it is always best to have the lamp burning. Although the present drawn wire Mazda lamp is very much stronger than its predecessor, the pressed filament lamp, this minor precaution of switching on the current for one or two minutes will often prevent broken lamps.

Drawn Wire Mazda Lamps

The drawn wire filament of the present Mazda lamp is many times stronger than the old pressed filament at any time during its life. This filament is continuous and of uniform size, so that uneven heating of any part of the filament is

impossible. This quality has much to do with the uniform life of this lamp.

The essential qualities of an incandescent filament are:—

1. High Melting point
2. Low vapor tension
3. Proper radiating characteristics
4. High resistance.

The higher the temperature at which a given incandescent filament operates the greater the quantity of light radiated in proportion to the energy used. The increase of light emitted is very marked at high temperatures, so that a slight increase of temperature of an incandescent filament means a large increase in the amount of light given off. The melting point of Tungsten is higher than those of other materials now used for filaments.

Low vapor tension is very important, as it is necessary that the filament does not evaporate rapidly at high temperatures. The drawn wire filament is especially ideal in this particular as tungsten has a low vapor tension.

The drawn wire tungsten filament is a poor radiator of heat, so that at the same temperature it will emit more light than a carbon filament, The superior light giving quality of the Mazda filament is due in part to the fact that a relatively large per cent. of the energy radiated falls within the limits of the visible spectrum,

High specific resistance is a desirable feature of an incandescent filament in that it allows the use of a thick and short filament. The positive temperature coefficient of the Mazda filament is another valuable feature, as it insures a more nearly uniform candle-power on fluctuating voltage. The effect of this positive temperature coefficient is shown in the curves on page 71.

Types of Mazda Lamps

Mazda lamps of the regular type are made in sizes of 10, 15, 20, 25, 40, 60, 100, 150 and 250 watts, for voltage ranges of 100 to 130, and 200 to 260, excepting the 15 and 20 watt lamps, which are made for 100 to 130 volts only. These are furnished in straight side bulbs designated by the letter "S," and the extreme diameter in eighths of an inch, as for example: the S-17 bulb has a diameter of 2-1/8 inches. The round bulb types are made in sizes of 15, 25, 40, 60, 100, 150, 400 and 500 watts for the 100 to 130 volt range, and in sizes of 25, 40, 60, 100 and 500 watts for the 200 to 260 volt range. The round bulbs are designated by the letter "G." A tubular lamp is made in the 25 watt size for the 100 to 130 volt range. This bulb is designated by the letter "T."

A concentrated filament lamp is made in the 100 watt size, round bulb, for the same voltage range.

The schedule of Mazda Sign lamps is shown complete on page 42.

Large style lamps for 20 volts, and below, are made as follows:—

2.5, 5, 7.5 and 10 watts in the S-14 bulb,

10, 12.5 and 15 watts in the S-17 bulb.

15, 20, 25 and 30 watts in the S-19 bulb.

2.5, 5, 7.5, 10, 12.5, 15, 20, 25 and 30 watts in the G-16½ bulb.

Mazda St. Series lamps are made for the following ampere ranges, and in the following candle-power sizes: 3. to 3.8 amperes in 32, 40, 60 and 80 C.P. sizes; 3.8 to 4.3 amperes in 32, 40, 60, 80, 100, 200 and 350 C.P. sizes; 5.1 to 5.9 amperes in 32, 40, 60, 80, 100, 200 and 350 C.P. sizes; 6.1 to 6.9 amperes in 32, 40, 60, 80, 100, 200 and 350 C.P. sizes; 7. to 8. amperes in 32, 40, 60, 80 and 350 C.P. sizes.

Train lighting lamps.—The Gem berth lights are made in sizes of 15 and 20 watts in the G-12 bulb. The Mazda Train Lighting and Compensator lamps are made as follows: 25 to 34 volts and 50 to 65 volts in sizes, 10, 15, 20, 25 and 50 watts in the round bulbs, and in sizes, 10, 15, 20, 25, 40 and 50 watts in the "S" bulbs.

Mazda Street Railway Lamps are made in 23 and 36 watt sizes. 100 to 130 volts, to operate five in series on circuits of 500 to 650 volts, and are especially selected for amperes. In addition to the standard Mazda Railway Lamps, Mazda Gauge Lamps of 10 volts are supplied for use in series with the standard lamps.

Automobile and Electric Vehicle lamps are given on page 36.

Gem Lamps

The Edison Gem or metallized filament lamp, although not as efficient as the Edison Mazda lamp, has a decided advantage over the Carbon lamp as a low initial cost unit.

A great many Central Stations give free renewals on Gem lamps, and are substituting them watt for watt for Carbons. The substitution watt for watt does not reduce the Central station load, but gives the customer a 20% increase in illumination for the same cost. The Gem lamp gives a whiter and more agreeable light and due to the positive temperature coefficient, is steadier on varying voltages.

In private plants running at full capacity, the adoption of Gem lamps will give an increase of illumination of 20%, or if additional space is to be illuminated, 20% of the generator capacity may be secured for this purpose by their substitution. In designing a new private plant the

18. Recommended substitutions of Gem for Carbon Lamps in Private Plant Service.

Carbon Lamps now in use	30W				
Operating eff. of Carbon Lamps	H		M		L
Gem Lamps to be substituted	30 w		30 w		30w
Operating eff. of Gem Lamps	H	M	M	L	L
Decrease in Wattage	0	1.1	0	1.0	0
% Increase in candle-power	8	0	8	0	10

Carbon Lamps now in use	50 W								
Operating eff. of Carbon Lamps	H			M			L		
Gem Lamps to be substituted	50 w			40w	50 w		40w		50w
Operating eff. of Gem Lamps	H	M	L	H	M	L	H	M	L
Decrease in Wattage	0	1.6	3.3	3.8	0	1.5	6.4	7.7	0
% Increase in candle-power	19	9	0	0	20	9	14	0	21

Carbon Lamps now in use	60 W										
Operating eff. of Carbon Lamps	H			M				L			
Gem Lamps to be substituted	50w	60 w		50 w		60w		50w			60w
Operating eff. of Gem Lamps	H	H	M	H	M	M	L	H	M	L	L
Decrease in Wattage	10	0	2	7.9	9.5	0	1 9	5.7	7.3	9	0
% Increase in candle-power	0	20	9	9	0	20	9	22	11	0	21

Carbon Lamps now in use	100W										
Operating eff. of Carbon Lamps	H			M				L			
Gem Lamps to be substituted	100W			80W		100W		80W			100W
Operating eff. of Gem Lamps	H	M	L	H	M	M	L	H	M	L	L
Decrease in Wattage	0	3.3	6.8	16.4	19	0	3.2	12.9	15.5	18.3	0
% Increase in candle-power	20	16	0	6	0	22	10	19	9	0	22

Carbon Lamps now in use	120W						
Operating eff. of Carbon Lamps	H	M		L			
Gem Lamps to be substituted	100W	100W		100W			80W
Operating eff. of Gem Lamps	H	H	M	H	M	L	H
Decrease in Wattage	20	15.8	19.1	11.4	14.7	18.2	31.4
% Increase in candle-power	0	11	0	24	13	2	0

H=High operating efficiency. M=Medium operating efficiency. L=Low operating efficiency.

19. Total Cost of Lighting with Gem Lamps for 1000 Hours Service.

Cost includes charges for Power and for Renewals. General Data on Lamps given in first part of table.

Size	30			40			50			60			80			100		
Rating	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Total Watts	30.0	28.9	27.9	40.0	38.7	37.3	50.0	48.4	46.7	60.0	58.0	56.0	80.0	77 4	74.6	100 0	96.7	93.2
Eff. W. P. C.	3.00	3.18	3.36	2.56	2.71	2.89	2.50	2.65	2.81	2.50	2.65	2.81	2.46	2.60	2.78	2.46	2.60	2.78
Mean Horiz. C P.	10.0	9.1	8 3	15.6	14.2	12.9	20.0	18.3	16.6	24.0	21.9	19.9	32.52	29.8	26.8	40.65	37.2	33.5
Hours Life.	1050	1500	2150	600	900	1300	700	1000	1500	700	1000	1500	700	1000	1500	650	950	1400
Kw-hrs. consumed during life	31.5	43.4	60.0	24.0	34.8	48.5	35	48.4	70.0	42.0	58.0	84.0	56.0	77.4	112.0	65.0	91.8	130.5
Cost of Lamp	$0.20			$0.20			$0.20			$0.20			$0.30			$0.30		
Renewal per 1000 hrs.	.190	166	093	.333	.222	154	.285	.200	.133	.285	200	133	428	300	20	461	.316	214
.005	340	.310	232	.533	415	.340	.535	.452	.356	.585	490	413	828	687	573	.961	799	680
0075	415	382	.312	633	.512	433	.660	473	.483	735	635	553	1.028	.880	757	1.211	1.041	913
010	.490	455	.372	733	.609	.527	785	694	.600	.885	880	693	1.228	1 014	946	1.461	1.283	1.146
Cost of Power 015	640	599	511	.933	802	713	1.035	936	.833	1.185	1.070	973	1.628	1 461	1.319	1 961	1.766	1.456
020	790	744	651	1.133	996	900	1.285	1.176	1.057	1.485	1.360	1.253	2.028	1.848	1.692	2.461	2.250	2.078
per 025	.940	.388	791	1.333	1.164	1.096	1.535	1.420	1.300	1.785	1.670	1.533	2.428	2.235	2.065	2.961	2.733	2.654
.030	1.090	1.033	931	1.533	1.383	1.273	1.785	1.662	1.594	2.085	1.950	1.813	2.828	2.622	2.522	3.461	3.227	3.010
Kilowatt-hour 035	1.240	1.177	1.071	1.733	1 576	1.459	2.035	1.904	1.827	2.385	2.085	1.993	3.228	3.009	2.811	3.961	3.700	3.476
.040	1.483	1.322	1.210	1 933	1.770	1.646	2.285	2.146	2.001	2.685	2.530	2.373	3.628	3.396	3.184	4.461	3.184	3.942
.050	1.783	1.611	1.498	2.333	2 267	2 019	2.785	2.630	2.458	3.285	3.120	3.033	4.428	4.170	4.070	5 461	5.151	4.874
.075	2.440	2.333	2.185	3.333	3.124	2.951	4.035	3.840	3.635	4.785	4.550	4.333	6.428	6.105	5.795	7.961	7.566	7.204
.100	3.190	3.056	2.883	4.333	4.092	3.886	5.285	5.050	4.803	6.285	6.000	5.733	8.428	8.040	7.660	10.461	9.986	9.534

H—High Operating Efficiency M—Medium Operating Efficiency L—Low Operating Efficiency

The above values are based on the List Price of clear Lamp, June, 1912. To obtain the cost of lighting at any charge per kw-hr for any lamp at a discounted price multiply the discounted price by 1000 and divide by the rated life for the efficiency at which the lamp is operated. This gives the renewal cost per 1000 hours at the discounted price. Subtract this from the corresponding renewal cost in the table and subtract the difference obtained from the corresponding total cost figures given above.

Any change in list price will not effect values calculated on a discount basis provided the new list price of the lamp is considered in calculating the renewal cost at the discounted price. Change in list price may also be treated as a discount in the calculation

use of Gem lamps will reduce the generator capacity, thereby cutting down the first cost of boilers, generators, and accessories and lowering the fixed charges in proportion. The decrease of wattage for private plants using Gem lamps in preference to Carbons is shown in Table 18. In Table 19 is shown the total cost for the operation of Gem lamps for 1000 hours service.

The curves in Fig. 22 show the changes in the total hours life of the Gem and Carbon lamps for varying efficiences. The Gem lamp, as will be seen from this curve, will burn three times as long as a Carbon lamp operating at the same efficiency. For a given hour's life the Gem lamp operates 17% more efficiently than the carbon lamp.

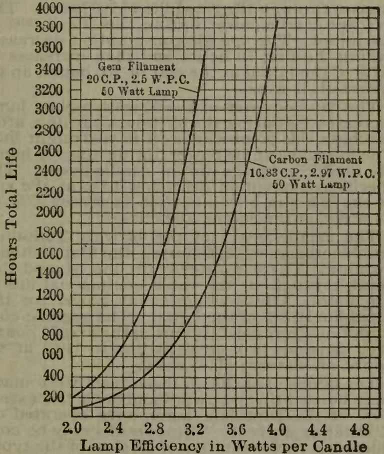


Fig. 22

Average Performance of Incandescent Lamps

The curves shown in Fig. 23 represent the average performance of the 60 watt Mazda, the 50 watt Gem, the 50 watt Carbon and the 40 watt Tantalum lamps, which have been tested in the laboratories of the General Electric Company, Harrison, N. J. These curves are obtained from lamps operating at the following efficiencies:—Mazda at 1.16 w.p.c., Gem at 2.5 w.p.c., Carbon at 2.97 w.p.c. and Tantalum at 1.79 w.p.c.

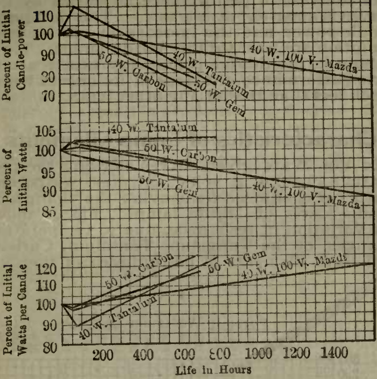
During the first 100 hours burning the candle-power of the 60 watt Mazda lamp increases 1% and decreases beyond that point. The average candle-power during the rated commercial life of 1000 hours is about 94% of the initial candle-power. After the first 100 hours the specific consumption increases to the rated life of the lamp, at which point it is 113.5% of the initial consumption, an increase of .15 w.p.c.

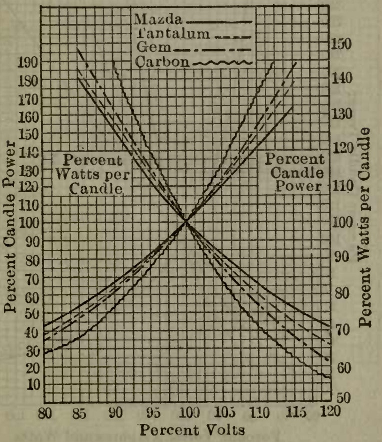
The candle-power of the Gem lamp increases 2% during the first 50 hours burning, then decreases through the rated life of 700 hours. The average candle-power during this life is 90% of the initial. The specific consumption decreases during the first 50 hours and then increases to 117% of the initial at the end of 700 hours, an increase of .42 w.p.c.

The candle-power of the 50 watt carbon lamp increases 3% during the 650 hours burning, after reaching this point it falls off in a straight line. The average candle-power during the 700 hours life is 87.75% of the initial candle-power. The specific consumption decreases 1.5% at the end of the 50 hours burning, then increases 25%, or .74 w.p.c. at the end of 700 hours.

The candle-power of the 40 watt Tantalum lamp increases to 105% during the first 70 hours burning. There is a steady decline beyond this point throughout the rated commercial life of 800 hours. The average candle-power for the rated life is 90% of the initial. The specific consumption decreases 11% during the first 70 hours, then increases in a straight line to 119% at 800 hours, an increase of .35 w.p.c.

The lamps upon which these tests were made were burned tip downward and with the exception of the Tantalum lamp were operated on alternating current. These results may be considered as representative of all sizes of the types which the above lamps represent, as each of these lamps closely approximate the average of their respective types. Especially is this true of the Mazda and Gem lamps for, due to the uniformity of the method observed in their manufacture, the lamps themselves give a very uniform performance, individual lamps varying very


Percent of Initial Candle-power
Percent of Initial Watts
Percent of Initial Watts per Candle
40-W. 100-V. Mazda
60 W. Carbon
40 W. Tantalum
50-W. Gem
Life in Hours
Fig. 23


Mazda
Tantalum
Gem
Carbon
Percent Watts per Candle
Percent Candle Power
Percent Candle Power
Percent Watts per Candle
Percent Volts
Fig. 24

little from the average results obtained by test. The contrast in performance as shown by the curves is apparent at a glance. The decline of candle-power and the increase in specific consumption are least for the Mazda lamps. Throughout its life this lamp has very nearly a uniform performance, the slope of its curves being much less than that of any other lamp.

Characteristics of Lamp Filaments

In Fig. 25 are given curves showing the percentage change in volts, amperes, watts, and watts per candle, accompanying the changes in candle-power of Mazda lamps. Fig. 26 shows the variation in resistance, due to temperature changes, of the Tungsten, Tantalum, Carbon, and Gem filaments in percentages of their re-

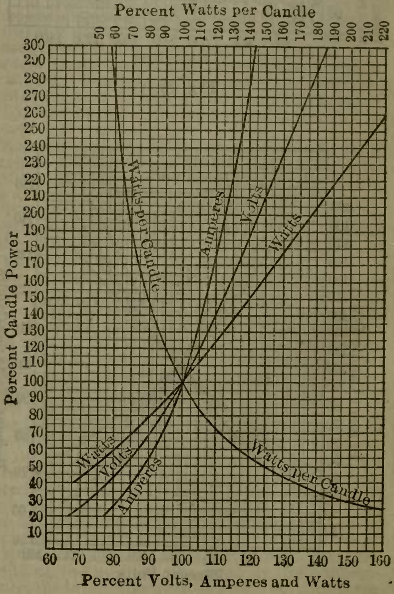


Fig. 25

spective cold resistances. As can be seen the Carbon lamp has a negative temperature coefficient so that an increased voltage means a decrease in resistance, thereby increasing the variation to a further extent. The Tungsten filament, however, has a positive temperature coefficient, and as an increase of voltage means a marked increase of resistance the change of current is small in proportion to the rise of voltage. Due to this positive temperature coefficient the Mazda lamp undergoes smaller changes in candle power, efficiency and life than does the carbon filament.

The variations of candle-power and efficiency with variations of voltage are shown by the curves in Fig. 24. As explained above these curves show that the Tungsten filament undergoes but small change as compared to the other types of filaments.

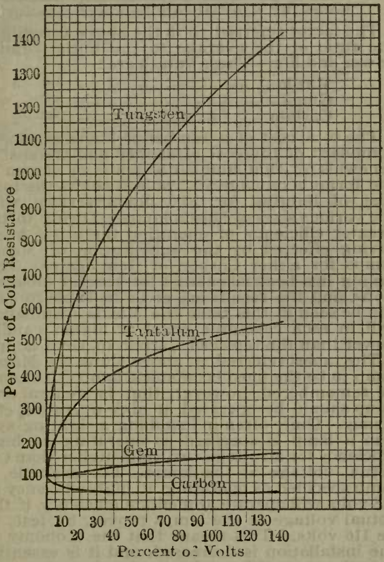


Fig. 26

Cost of Light

The average total cost per unit of light produced by incandescent lamps may be considered as made up of two elemental parts,—cost of energy and the cost of renewals. It is evident, then, that the most economical efficiency at which a lamp can be operated is that at which the sum of these expenditures is lowest. As the cost of energy becomes higher, or as the cost of renewals becomes lower, the efficiency should be increased. This is shown by the curves in Figure 28. These curves show the economical efficiencies at which a 250 watt Mazda lamp should operate for various charges per kilowatt hour of energy.

The average total cost in dollars of 1000 candle hours of light is equal to

$$\frac{\text{Cost per kw-hr. in dollars} \times \text{initial efficiency}}{\text{factor}} + \frac{\text{cost of lamp in dollars} \times 1000}{\text{hours life} \times \text{initial candle-power} \times \text{factor.}}$$

The factor referred to in the above formula is the ratio of the average to the initial candle-power and life. These values are:—

Mazda	.95
Gem	.85
Carbon	.80

The total cost of a number of hours service is composed of the cost of energy and the cost of renewals for that number of hours as shown in the formula on page 5. Table 21 shows the total cost of lighting for 1000 hours service with the various sizes of Mazda lamps, Owing to the greater efficiency of operation there is a great saving effected by the substitution of Mazda lamps for either Carbon or Gem lamps. This saving has been calculated for several substitutions, and the results are given in Table 20. As can be seen in this table the Mazda installation will in each case give equal or higher candle-power than the replaced Carbon or Gem lamps.

The tables referred to above show the Mazda lamp to be the most economical lamp. It should be remembered, however, that in general this lamp should be operated at high operating efficiency. Quite often in installing a lighting system a lamp is specified as operating at high efficiency for a voltage two volts higher than the actual voltage at the lamps. For example, a lamp specified as operating at high efficiency at 118 volts will operate at medium efficiency if the actual voltage at the lamps proves, by test, to be 116 volts. This means that the economy of the installation is decreased, and it is essential that the user of incandescent lamps makes sure that his lamps are operating at the proper efficiency. Too often a lamp that has outlived its

rated life is allowed to remain in the circuit. This not only mars the appearance of the installation but also cuts down the efficiency. The wattage consumption remains practically the same, so that the user of a lamp that has passed its rated life by several hours, is paying for energy that does not produce the amount of light that could be gained by renewal.

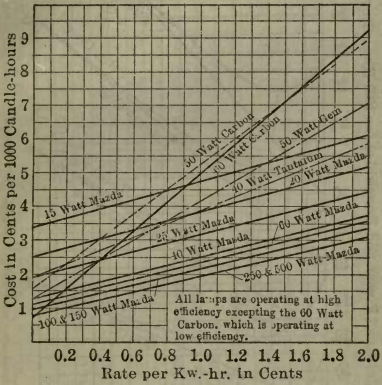
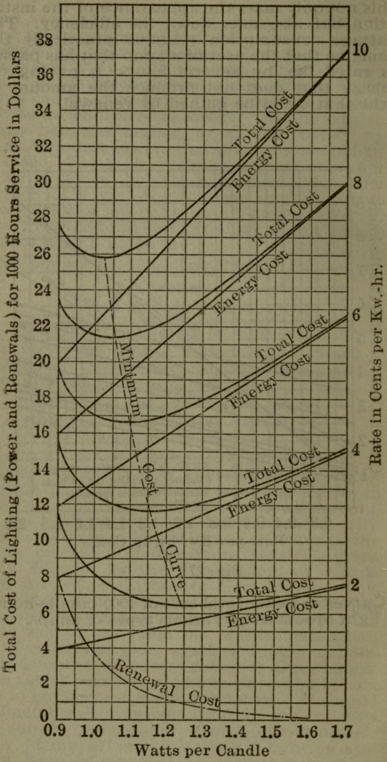


Fig. 27

Curves showing total cost of 1000 candle-hours of light produced by various types of lamps.



Total Cost of Lighting (Power and Renewals) for 1000 Hours Service in Dollars
Rate in Cents per Kw.-hr.
Watts per Candle
0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
2 4 6 8 10
Total Cost
Energy Cost
Minimum Cost Curve
Renewal Cost

Fig. 28

20. Saving in Total Operating Cost of Mazda Lamps over Carbon and Gem for 1000 Hours' Service, Including Power and Renewals.

Mazda Lamps to replace		With 25 W. Mazda 1.90 C. P. M. O. E. over		With 40 W. Mazda 31.7 C. P. M. O. E. over		With 60 W Mazda 48.4 C. P. M. O. E. over		With 100 W Mazda 82.8 C. P M. O. E over	
Gem or Carbon		50 W. 16.8 C. P. Carbon H. O. E.	50 W. 20 C. P Gem M. O. E.	100 W. 30.5 C. P. Carbon M. O. E.	80 W. 32.5 C. P. Gem H. O. E.	3-50 W 16.8 C. P. Carbon H. O. E.	2-60 W. 24 C. P. Gem H. O. E.	2-120 W. 40.4 C. P. Carbon H. O. E.	2-100 W. 40.7 C. P. Gem H. O E.
Mazda Hours' Life		1300	1300	1300	1300	1300	1300	1300	1300
Carbon or Gem Hours' Life		700	1000	850	700	700	700	600	650
Mazda Renewals		0.385	0.385	0.423	0.423	0.577	0.577	0.769	0.769
Gem or Carbon Renewals		0.228	0.200	0.282	0.428	0.495	572	0.800	923
Saving in Renewal Cost		-0.157	-0.185	-0.141	-0.005	-0.082	-0.005	-0.031	0.154
Mazda Kw-hrs. per 1000 Hrs.		24.3	24.3	38.9	38.9	58.3	58.3	97.2	97.2
Carbon or Gem Kw-hrs. per 1000 Hrs.		50	48.4	96.4	80.	150	120	240	200
Saving in Kw-hrs. per 1000 Hrs.		25.7	24.1	57.5	41.1	91.7	61.7	142.8	102.8
								Total Saving in Power and Renewals	
Cost per Kw-hr in Cents	1	0.100	0.056	0.434	0.416	0.835	0.612	1.459	1.182
	2	0.357	0.297	1 009	0.827	1.752	1.229	2.887	2.210
	3	0.614	0.538	1.584	1.238	2 669	1 846	4.315	3.238
	4	0.871	0.779	2.159	1.649	3.586	2.463	5.743	4.266
	5	1.128	1.020	2 734	2.060	4.503	3.080	7 171	5.294
	6	1.385	1.261	3.309	2.471	5.420	3.697	8.599	6.322
	7	1.642	1.502	3.884	2.882	6 337	4.314	10.027	7.350
	8	1.899	1.743	4.459	3.293	7 254	4.931	11.455	8.378
	9	2.156	1.984	5.034	3.704	8.171	5.548	12.883	9.406
	10	2.413	2.225	5 609	4.115	9.088	6.165	14.311	10.434

Mazda Lamps to replace		With 150 W Mazda 125 C. P. M. O. E. over		With 250 W Mazda 213 C. P. M. O. E. over		With 400 W Mazda 341 C. P. M. O. E. over		With 500 W Mazda 426 C. P M. O. E. over	
Gem or Carbon		3-120 W. 40.4 C. P. Carbon H. O. E.	3-100 W. 40.7 C. P. Gem H. O. E.	10-60 W. 20.2 C. P. Carbon H. O. E.	11-50 W. 20. C. P. Gem H. O. E.	10-100 W. 13.6 C. P. Carbon H. O. E.	10-80 W. 32.5 C. P. Gem H. O. E.	11-120 W. 40.4 C. P. Carbon H. O. E.	11-100 W. 40.7 C. P. Gem H. O. E.
Mazda Hours' Life		1300	1300	1300	1300	1300	1300	1300	1300
Carbon or Gem Hours' Life		600	650	700	700	600	700	600	650
Mazda Renewals		1.270	1.270	1 770	1.770	3.190	3.190	3.500	3.500
Gem or Carbon Renewals		1.200	1.382	2.285	3.140	4.000	4.280	4.400	5.075
Saving in Renewal Cost		-0.070	0.112	0.515	1.370	810	1 090	0.900	1.575
Mazda Kw-hrs. per 1000 Hrs.		145.6	145.6	243	243	389	389	486	486
Carbon or Gem Kw-hrs. per 1000 Hrs.		360	300	600	550	1000	800	1320	1100
Saving in Kw-hrs. per 1000 Hrs.		214.4	154.4	357	307	611	411	834	614
		Total Saving in Power and Renewals							
Cost per Kw-hr in Cents	1	2.074	1.656	4.085	4.440	6.920	5.20	9.24	7.715
	2	4.218	3 200	7.655	7.510	13.030	9.31	17.58	13.855
	3	6.362	4.744	11.225	10.580	19.140	13.42	25.92	19.995
	4	8.506	6.288	14.795	13.650	25.250	17.53	34.26	26.135
	5	10.650	7.832	18.365	16.720	31.360	21.64	42.60	32.275
	6	12.794	9.376	21.935	19.790	37.470	25.75	50.94	38.415
	7	14.938	10.920	25.505	22 860	43.580	29.86	59.28	44.555
	8	17.082	12.464	29.075	25.930	49.690	33.97	67.62	50.695
	9	19.226	14.008	32 645	29.000	55.800	38.08	75.96	56.835
	10	21.370	15.552	36 215	32 070	61 910	42.19	84.30	62.975

H—High Operating Efficiency. M—Medium Operating Efficiency. The values of the above table are based on list prices of clear lamps, June, 1912. To obtain the saving in operating cost at a discounted rate.—Multiply the Mazda renewal cost by the Mazda discount factor and multiply the Gem or Carbon renewal cost by the Gem or Carbon discount factor. Subtract the former result from the latter and subtract algebraically this remainder from the value of the "saving in renewal cost" in the table. Subtract algebraically the remainder thus obtained from the values in the proper columns of total saving. Any change in list price will not effect values calculated on a discount basis, provided the new list price of the lamp is considered in calculating the renewal cost at the discounted price Change in list price may also be treated as a discount in the calculation

21. Total Cost of Lighting with Mazda Lamps.

Comparison of Lamps covering 1000 Hours Service. Cost includes Cost of Power and Renewals, with Power at various Rates. General Data on Lamps Given in first part of Table.

Size	15 Watt			20 Watt			25 Watt			40 Watt			60 Watt		
Rating (Operating Eff.)	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Total Watts	15	14.6	14.2	20	19.4	18.8	25	24.3	23.6	40.0	38.9	37.8	60.0	58.3	56.6
Actual Watts per C. P.	1.31	1 37	1.43	1 28	1.33	1.38	1.23	1.28	1.33	1.18	1.23	1.28	1.16	1.21	1.26
Actual C. P. (Mean Horiz.)	11.7	10.7	10.0	15.6	14.4	13.6	20.3	19 0	17.7	33.9	31.7	29.5	51.7	48.4	45.1
Hours Life	1000	1300	1700	1000	1300	1700	1000	1300	1700	1000	1300	1700	1000	1300	1700
Kw-hrs. consumed during Life	15	19	24.2	20	25.2	32.	25	31.6	40.2	40 0	50.5	64.2	60.0	75 8	96.3
Cost of Lamps List Price	$0.500			$0 500			$0.500			$0 550			$0.750		
Cost of Renewals per 1000 hrs.	0.500	0.385	0.294	0.500	0.385	0.294	0.500	0.385	0.294	0.550	0 423	0.323	0 750	0.577	0.441
Cost of Power per Kilowatt-Hour	**Total Cost (Power and Renewals) for 1000 Hours.**														
$0.0050	0.575	0.458	0.365	0.600	0.482	0.388	0.625	0.506	0.412	0.750	0.617	0.512	1.050	0.868	0.713
0.0075	0.582	0.494	0.400	0.650	0.530	0.435	0.698	0.567	0.470	0.850	0.715	0 606	1 201	1.014	0.854
0100	0.650	0.531	0.436	0 700	0.579	0.482	0.750	0.627	0.530	0.950	0 812	0.701	1.350	1.160	0.996
0150	0.725	0 604	0.507	0.800	0.676	0 576	0.875	0.749	0.648	1.150	1.007	0.891	1.650	1 451	1.279
.0200	0.800	0.677	0 578	0.900	0.783	0.670	0.980	0.871	0.766	1.350	1.201	1.079	1 950	1.743	1.562
.0250	0.875	0.750	0.649	1.000	0.870	0.764	1.125	0.992	0.888	1.550	1.395	1.268	2 250	2.027	1.835
.0300	0.950	0.823	0.720	1 100	0.967	0.858	1.250	1.114	0.996	1.750	1.590	1.458	2.550	2.326	2.128
.0350	1 025	0.896	0.791	1.200	1 064	0.952	1.376	1.225	1.114	1.950	1.795	1.647	2.850	2.617	2.411
.0400	1.100	0.969	0 852	1.300	1.161	1.046	1.500	1.357	1.238	2 150	1.979	1.835	3.150	2 909	2.694
.0500	1.250	1.115	1.044	1.500	1.355	1.234	1.750	1.600	1.474	2.550	2.368	2.213	3.750	3.492	3 260
.0750	1.625	1.480	1.359	2.000	1.840	1.704	2.375	2.207	2.064	3.550	3.340	3.161	5.250	4.949	4.675
.1000	2.000	1.845	1.714	2.500	2.325	2.174	3.000	2.805	2.654	4.550	4.313	4.103	6.750	6.407	6.090

H—High Operating Efficiency. M—Medium Operating Efficieny. L—Low Operating Efficiency

The above values are based on the list prices of clear lamps, June, 1912. To obtain the cost of lighting at any charge per kw-hr for any lamp at a discounted price, multiply the discounted price by 1000 and divide by the rated life for the efficiency at which the lamp is to be operated. This gives the renewal cost per 1000 hrs. at the discounted price. Subtract this from the corresponding renewal cost in the table, and subtract the difference obtained from the corresponding total cost figures given above. Any change in list price will not effect values calculated on a discount basis, provided the new list price of the lamp is considered in calculating the renewal cost at the discounted price Change in list price may also be treated as a discount in the calculation.

21. Total Cost of Lighting with Mazda Lamps—Continued.

Comparison of Lamps covering 1000 Hours Service. Cost includes Cost of Power and Renewals, with Power at various Rates. General Data on Lamps Given in first part of Table.

Size		100 Watt			150 Watt			250 Watt			400 Watt			500 Watt		
Rating (Operating Eff.)		H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Total Watts		100	97.2	94.4	150	145.6	142.0	250	243	236	400	389	378	500	486	472
Actual Watts per C. P.		1.13	1.18	1.23	1.12	1.17	1.22	1.10	1.14	1.18	1.10	1.14	1.18	1.10	1.14	1.18
Actual C. P. (Mean Horiz.)		88.5	82.8	77.1	134	125	116	227	213	199	163	341	319	454	426	398
Hours Life		1000	1300	1700	1000	1300	1700	1000	1300	1700	1000	1300	1700	1000	1300	1700
Kw-hrs. consumed during Life		100	126.2	160.2	150	180 2	241	250.0	316	401.2	400.0	506	641.3	500	632	803
Cost of Lamps List Price		$1.100			$1.650			$2.300			$4 15			$4.55		
Cost of Renewals per 1000 hrs.		1.100	0.769	0.647	1.650	1.270	0.970	2.300	1 770	1.353	4.150	3.190	2.440	4.550	3.500	2.675
		Total Cost (Power and Renewals) for 1000 Hours.														
	$0.0050	1.600	1.255	1.119	2.400	1.998	1.680	3.550	2.985	2.533	6.150	5.135	4.330	7.050	5.930	5.035
	0.0075	1.850	1.498	1.354	2.795	2.362	2.036	4.175	3.592	3.123	7.150	6.077	5.275	8.300	7.145	6.210
	.0100	2.100	1.741	1.591	3.150	2.726	2.390	4.800	4.200	3.713	8.150	7.080	6.220	9.550	8.360	7.395
Cost of Power	.0150	2 600	2.227	2.058	3 900	3.456	3.100	6.050	5.425	4.893	10.150	9.025	8.110	12.050	10.790	9.755
	.0200	3.100	3.713	2.535	4.650	4.182	3.804	7.300	6.630	6.073	12.150	10.970	10.000	14.550	13.220	12.115
per	.0250	3.600	3.199	3.006	5 400	4.909	4.515	8.550	7.845	7.253	14.150	12.915	11.890	17.050	15.650	14.470
	.0300	4.100	3.685	3.479	6.150	5.638	5.230	9.800	9.060	8.433	16.150	14.860	13.780	19.550	18.080	16.835
Kilowatt-Hour	.0350	4.600	4 171	3.949	6.900	6.373	5.940	11.050	10 285	9.613	18.150	16.830	15 670	22.050	20.510	19.195
	.0400	5.100	4.657	4.423	7.650	7.094	6 658	12.300	11.490	10.793	20.150	18 750	17.560	24.550	22.940	21.555
	.0500	6.100	5.629	5.367	9.150	8.550	8.080	14.800	13.920	13.153	24.150	22.640	21.340	29.550	27.800	26.275
	.0750	8.600	8.059	7.727	13.900	12.185	11.640	21 050	19.985	19.053	34.150	32.365	30.790	42.050	39.950	38.075
	.1000	11.100	10.489	10.087	16 650	15.830	15.170	27 300	26.070	24.953	45.150	42.090	39.240	54.550	52.100	49.875

H—High Operating Efficiency. M—Medium Operating Efficiency. L—Low Operating Efficiency

The above values are based on the list prices of clear lamps, June, 1912. To obtain the cost of lighting at any charge per kw-hr. for any lamp at a discounted price, multiply the discounted price by 1000 and divide by the rated life for the efficiency at which the lamp is to be operated. This gives the renewal cost per 1000 hrs. at the discounted price. Subtract this from the corresponding renewal cost in the table, and subtract the difference obtained from the corresponding total cost figures given above. Any change in list price will not effect values calculated on a discount basis, provided the new list price of the lamp is considered in calculating the renewal cost at the discounted price. Change in list price may also be treated as a discount in the calculaton.

Energy Losses in Incandescent Lamp Filaments.

Transmission of electrical to thermal power in incandescent lamps is, so far as known, perfect and without loss. The heat produced in the filament must, in the steady state, escape at the same rate at which it is generated. The escape, or heat dissipation, from the filament must occur by radiation, conduction, or convection. Radiation is believed to be an electro-magnetic process whereby electro-magnetic waves are set up in the space surrounding the filament, and are transmitted outwardly in all directions at the velocity of light. All the light usefully delivered by the lamp is due to this radiation, and depends upon how much radiation is produced within the limits of the visible spectrum. The major part of the radiation given off by the filament is non-luminous, that is, it has a frequency either too low or too high to be perceived by the eye. Moreover, some of the radiation in passing through the glass walls of the lamp is absorbed and heats the glass, so that this lost radiation is given off finally by air convection from the bulb. A percentage of the heat escapes from the filament by conduction through the leads and through the supporting anchors. A part of the heat escapes from the filament into the surounding gas by convection. This is necessarily only a small part, however, and depends upon the condition of the vacuum.

The ratio of total energy radiated to the power consumed is spoken of as the relative radiation capacity. The ratio of luminous radiation to the total radiation is called the light effect and the ratio of luminous power to the total power consumed is the useful effect or net efficiency. The determination of these relations is difficult and various schemes have been used for their measurement. The values given in the table are conclusions arrived at by different experiments, and an average of the values for each relation may be considered as a fair approximation.

In the pressed filament type of lamp it was necessary that the filament have good electrical contact with the bottom anchors, and a good electrical contact is a good thermal contact. In the drawn wire type the only electrical contacts are at the lead wires, consequently the heat loss due to conduction is less. This means an increased ratio of total radiated energy to total power consumed. A comparatively large percentage of the radiation from the drawn wire filament is within the visible spectrum, so that this lamp has a high ratio of luminous radiation to total radiation. As both of these ratios are high, the lamp has a high net efficiency.

Source of Light	Relative Radiating Capacity	Light Effect	Net Eff.	W.P.C.	Authority
Carbon	61.9	2.85	1.75	3.8	a
			1.56	3.1	
115 Volt			2.2	2.85	c
			3.1	2.64	
250 Volt		2.42-3.42		3.1	b
Tantalum	64.8	4.26	2.75	2.02	a
		6.35-6.66		1.97	b
Osram	75.6	4.63	3.5	1.51	a
Tungsten 250 Volt		7.6-9.39		1.31	b
130 Volt		6.43-6.61		1.28	b
			4.5	1.31	
115 Volt			5.2	1.18	c
			6.00	1.05	

References:

Electrical World, March 9, 1911, Page 593.
a- Elek. Zeit., March 16, 1911, G. Leimbach, E. World, April 27, 1911.
b- Electrical World, May 18, 1911, R. A. Houston,
c- Elek. Zeit., Oct. 12, 1911, J. Russner, Electrical World, April 20, 1911, Page 982.

Prevention of Static Effects

Incandescent lamp filaments are sometimes affected by static electricity from moving belts, silk, etc. As a means of preventing any trouble from this source a metallic comb consisting of a row of sharp projecting teeth is placed on the top and under side of the belt, and securely grounded. Though this method is fairly effective, when properly applied, in places like silk and paper mills it is very difficult to apply it to any appreciable advantage without interfering with the operatives.

Another device, which has found considerable favor in many mills, consists of a small motor generator set with transformer. The current is transmitted to two inductor bars, extending across the width of the machine, and about three inches above the moving bands of paper, silk or wool threads. These inductor bars have several fine wire points which carry the electric charge.

Since these points are charged by alternating current, they carry both positive and negative charges. Consequently it makes no difference which of the two kinds the hostile charge may be, as it will be neutralized by an opposite charge from the wire points.

The cheapest and perhaps simplest way to overcome the harmful effects on incandescent lamps is to form a protection for each individual lamp unit. This is easily accomplished by means of a wire guard around the lamp. As the purpose of the guard is to neutralize the static flux before it can collect on the lamp, it is evident that the smaller the meshes the more effective it will be, though, of course, they must not be so small as to noticeably reduce the amount of light from the lamp. Where several lamps are combined in one cluster the same result can be obtained by using one bowl shaped wire guard underneath.

The wire guard can be grounded by means of a wire extending up along the fixture to some iron work in the building, or to a nearby gas or water pipe that will make a good ground. This wire, when intertwined in the lamp cord, should be heavily insulated, in order to avoid any possible short circuit. A three wire lamp cord would be very satisfactory for this arrangement, the third wire being used on the lamp guard. By using a wire guard which fastens to the bulb of the lamp there will be no metal connections between the socket and the grounded guard, thereby making this entire arrangement strictly in accordance with the underwriters' rules.

Fixtures

The selection of fixtures in an installation depends on the surroundings and no set rules can be given to govern the selection. When we consider that in a successful installation of an artistic or decorative nature the fixtures and illuminants must blend so well with the general scheme that attention is not attracted to them, and a person having left the room is unable to describe the lighting fixtures, we can readily see that the designer must have had a considerable sense of harmony. The manufacturers of electrical equipment have, in the last ten years, made rapid strides in the development of a great variety of designs. There is a wide range from the plain designs of cheap tubing to the more expensive ornamental designs, but there is a wider range within the latter class itself. The use of fixtures, however, is often a source of danger, unless the proper precautions are observed. The National Board of Fire Underwriters has laid down strict rules regarding the use of fixtures which are given in the National Electric Code on Page 110.

Visual Acuity

Visual acuity is, in its broad sense, as the name implies, acuteness of vision. It may, however, be better understood by a study of the means used to measure this acuteness of vision. Fechner performed a series of experiments, in which he varied the intensity of a shadow on an illuminated background, and determined the minimum difference in illumination distinguishable. He expressed this difference in illumination in the form of a ratio, and this latter became known as Fechner's constant, and is a basis of visual acuity measurements. This constant is 1/101 and it means that when we have a 1% difference of intensity we can just distinguish this difference in intensity, provided the two surfaces illuminated are in juxtaposition, and can be seen simultaneously. The constant does not hold good for very low or very high intensities.

Any object focused in the retina of the eye subtends a certain angle at the eye, and from this angle and the focal length of the eye may be determined the size of the image on the retina. Helmholz conducted a series of experiments to determine the smallest visual angle and the size of the focused image. Later this work was supplemented by Snellen, and the results of his investigations embodied in the reading chart bearing his name. Snellen determined that the smallest visual angle for the average eye was one minute, and on this basis he built letters giving the distance at which the normal eye should just perceive them. For instance, we find

E

for the above letter "E" the normal reading distance is 20 ft. In this letter we have vertically two spaces and three lines; each space and line must subtend an angle of one minute at 20 feet or the entire letter subtend an angle of five minutes. Now, if a person can just distinguish this letter at 21 feet we say he has a visual acuity of 21/20, or 1.05, and we have another means of measuring acuteness of vision. This is by far the most popular conception of the term, and this chart is often used by opticians in testing eyes.

Visual acuity is affected by the intensity of the light, the color of the light, and the condition of the eye (Contraction of the pupil); also it is affected by the health, loss of sleep, mental and physical fatigue and fatigue of the eye itself. However, the effect of fatigue is much less than

is popularly supposed.

The effect of variation on intensity may be shown by the following curve in which acuity is plotted as ordinates and intensity of illumination as abscissae.

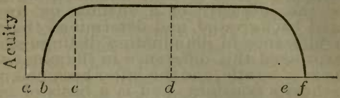


Fig. 29

a—Total darkness.

b—Threshold point where vision begins, about .00002 (by Aubert).

c—About 2⅛ foot candles.

f—Where vision ceases at extremely high intensities probably above 4000 foot candles.

The point that should be noted is the very small variation in acuity from **c** to **e**, and it is between these points that Fechner's constant holds good, slight variations being due to the fact that there is a slight increase of the acuity up to **d** and a gradual falling off from there to **e.**

The effect of the color of the light on acuity has also been thoroughly established, but exact values are hard to obtain The fact that monochromatic colored lights present many difficulties in photometry, and are hard to obtain, probably accounts for the scarcity of reliable data. It is undoubtedly a fact, however, that with high candle-powers the part of the spectrum which gives maximum acuity is about the orange-yellow, while with low intensities this point shifts to the yellow-green part of the spectrum. This shifting of the maximum acuity point was first noticed by Purkinje, and was thereafter known as the Purkinje effect. The luminosity curve for the different parts of the spectrum has been investigated to quite an extent, and it is probable that the acuity follows this curve in a general way.

Several experiments in acuity with the use of different illuminants used under different conditions have been performed by Mr. Ashe, at Harrison, and this data has been published from time to time in the various engineering periodicals, and the Transactions of the Illuminating Engineering Society.

In considering any illuminant or form of illumination the visual acuity values obtained with a certain foot candle intensity are by no means the final criterion by which to judge any illuminant or installation. The æsthetic side which embraces color adaptability and general appearance

must also be considered. Then too, we have a more technical side which embraces distribution, watts per effective lumens, etc., but the fact still remains that visual acuity is an important factor both in installation and research work.

Intrinsic Brilliancy of Light Sources.

Louis Bell, Ph. D.

	Candle-power per sq. in.
Moore tube	0.3-1.75
Frosted incandescent	2-5
Candle	3-4
Gas Flame	3-8
Oil lamp	3-8
Cooper-Hewitt lamp	17
Welsbach gas mantle	20-50
Acetylene	75-100
Enclosed A. C. arc	75-200
Enclosed D. C. arc	100-500
Incandescent Lamps	
Carbon 3.5 watts per candle	375
Carbon 3.1 watts per candle	480
Gem 2.5 watts per candle	625
Tantalum 2.0 watts per candle	750
"Mazda" 1.25 watts per candle	875
"Mazda" 1.15 watts per candle	1000
Nernst 1.5 watts per candle	2200
Sun on horizon	2000
Flaming arc	5000
Open arc lamp	10,000-50,000
Open arc crater	200,000
Sun 30° above horizon	500,000
Sun at zenith	600,000

Luminescence

Light in any form is produced either through temperature radiation or through luminescence, or a combination of the two.

When light is produced by simply heating such ordinary material as carbon or a metal to a high temperature, the light is said to be produced by temperature radiation. Examples of this are the radiation of light from (a) heated carbon particles in an ordinary flame as of a candle, kerosene lamp, or gas flame, (b) the crater light of an open or enclosed carbon arc, or (c) the light of an incandescent lamp filament.

The term luminescence is applied to radiation through more complex action, involving a change in the material. There are a number of allied phenomena included in this class which are more or less indefinitely classified and defined.

Phosphorescence and Fluorescence are perhaps the most familiar forms of luminescence.

Phosphorescence is the phenomenon peculiar to certain substances such as calcium sulphide which gives off a glow after having been exposed to light. This is also known as photo-luminescence. Phosphorescence is also applied to describe light which accompanies the slow oxidization of phosphorus, although, this is more scientifically designated as chemi-luminescence. The light of the fire-fly is an example of chemi-luminescence.

Fluorescence refers to the property of sulphate of quinine and certain other materials by which they glow when exposed to light, the light emitted being of a lower rate of vibration than the impinging light. A common example of this is the transformation of invisible ultra-violet radiation into visible light by willamite.

The color of phosphorescent and fluorescent light does not usually correspond to the usual superficial color of the material. Moreover, in the case of materials subject to both phenomena, the fluorescent color often differs from the phosphorescent.

Luminescence may be induced by heat or electric energy. The light from a flaming arc lamp is usually ascribed to luminescence induced by heat generated from the electric current. In the case of gas mantles, investigators do not agree as to whether or not luminescence is involved in the light production.

Electro-luminescence occurs in the mercury vapor arcs and vacuum tube light sources. Although heat is present, there is reason to believe that the action takes place without its forming an intermediate step.

Luminescence is of especial interest in connection with the development of new illuminants, since with our present knowledge it seems to offer the greatest possibilities in the way of increased efficiency. Investigations of the light of the fire-fly indicate an almost perfect efficiency, although, its color in high intensities would be rather disagreeable.

This suggests, however, the possibility of securing much higher efficiency than that of our present artificial illuminants, even if it were not carried so far as to make a sacrifice in color.

Instructions for Ordering Lamps

To avoid misinterpretation of orders it is advisable that customers mention the following facts on each order:—

1. QUANTITY (number of lamps desired).
2. CLASS (Gem, or Mazda).
3. SIZE OF LAMPS (in watts, whether 40 watt, 100 watt, etc. If Street Series lamps are ordered give **amperes** and **candle-power.** If Mazda miniature lamps are ordered give **candle-power**).
4. CIRCUIT VOLTAGE (voltage at the lamp socket).
5. OPERATING EFFICIENCY (whether High, Medium or Low).
6. STYLE OF BASE (whether Medium Screw, Mogul Screw, Bayonet Candelabra, etc., and also the style number of the base. When lamps are scheduled as being manufactured with skirted and unskirted bases, as for example, the regular 40 watt Mazda, the order should distinctly specify whether skirted or unskirted base is desired).
7. TYPE OF BULB (whether Straight, Round or Tubular).
8. WHETHER LAMPS ARE DESIRED CLEAR, BOWL FROSTED OR ALL FROSTED. If colored lamps are desired, state color and whether lamps should be superficially colored or made of natural colored glass.

When lamps are furnished with the single voltage label, item No. 5 should be omitted.

Order Standard Packages.

When ordering lamps, customer should bear in mind that the manufacturer stores the **lamps packed in standard packages.** An order for quantities **less than standard package incurs delay and needless expense** on account of the repacking which necessarily has to be done in order to supply a broken package.

It is also to the customer's advantage to **adhere to standard lamps listed in the schedules.** The large variety of lamps and voltage ranges which are listed should permit the selection of lamps that will give satisfactory results under any conditions.

Whenever it becomes necessary to order special lamps, the manufacturer reserves the right to fill all such orders either short or in excess of the exact quantity ordered within the limits of 10 per cent. This is necessary on account of the fact that it is impossible to always produce an exact quantity of any special lamp.

If the above directions are carefully followed when orders are placed, needless errors and delays will be avoided.

Predominating Color of Light from Various Sources.

Illuminant	Color
Average Daylight	White
High sun	Yellowish White
Low sun	Yellow to orange red
Sky light	Bluish white
Arc-D.C. open	White slight yellow tint
Arc-D.C. enclosed, 80 V.	" " " "
Arc-D.C. intensified	" " " "
Arc-D.C. enclosed, 150 V.	Purplish or violet tint
Arc-A.C. enclosed, 75 V.	Slight purple tint
Arc-Magnetite	Approximately white
Arc-Flame (yellow carbons)	Orange yellow
Arc-Flame (white carbons)	Approximately white
Arc-Flame (red carbons)	Orange red
Nernst Lamp	Yellowish tint
Tungsten-(1.25 wpc.)	Nearly white, slight yellow tint
Incandescent (carbon)	Yellow tint
Acetylene flame	Yellow tinted
Mercury arc	Blue green
Gas Mantle	Greenish white or amber
Gas, ordinary burner	Pale orange yellow
Kerosene	Orange yellow
Candle	Orange
Moore Tube (CO_2)	Approximately white
Moore Tube (N_2)	Salmon pink

Electric Circuits

With Special Reference to Incandescent Lamps

There are two distinct systems for distributing electrical energy; namely, series and parallel systems. The former is known as the constant current system and the latter as the constant potential. A combination of the above systems is used for sign lighting and is known as the parallel group in series, or simply the parallel series method of distribution.

Series System

In the series system, the same current flows through all the lamps and is usually maintained at a fixed value by a regulator or a constant current transformer, as used in alternating current circuits. In this system, the voltage of the generator or transformer directly supplying energy to the system is divided according to the resistance of the lamps. If all the lamps have the same rating and there are ten lamps in a series circuit of 100 volts, then there is a voltage of 100 volts divided by 10 lamps or 10 volts across the terminals of each lamp.

For series systems all lamps should have approximately the same current rating. Lamps are cut out of a series system, not by turning off the lamp, that is, by opening the socket, but by short-circuiting the lamp to be cut out of the system.

In an incandescent series system each lamp socket is equipped with an automatic cut-out which short circuits the filament of the lamp in case of failure or burnout. A thin insulating film, which will puncture under a potential of 75 to 100 volts, but which withstands lower voltages is placed between two contact points. When a lamp circuit is broken the full feeder voltage is impressed upon the contact points, breaking down the insulating film, thereby restoring the circuit by bridging the filament.

With alternating current the constant current transformer supplying the current is usually designed so as to maintain the current constant under all conditions independent of the number of lamps in the circuit.

Parallel System

In this system the voltage is approximately constant and the current is divided between the lamps according to their resistance. This is called the parallel system because the lamps

are used in parallel or multiple. This system is used almost exclusively for interior lighting. The 100-130 volt lamps operate at a better efficiency than 200-260 volt lamps, so that on a 200-volt circuit 2-100 volt lamps are used in series instead of 1-200 volt lamp. This scheme, however, has two disadvantages; first, if one lamp fails the circuit is open and both lamps are out of service; second, the lamps used in series must have approximately the same current and voltage ratings, as it is impossible to satisfactorily operate lamps of different wattages in series.

The advantage, however, of the 200-volt system is that for the same energy transmitted the current is halved so that the amount of copper necessary for the installation is quartered, thereby securing great economy in construction. To make use of this advantage and to do away with the disadvantage of two lamps in series the Edison Three-Wire System was designed. By this scheme two generators in series supply power to the outside wires. The lamps are connected between these outside wires and the middle or neutral wire, which is connected between the two generators. Now the burning out of a lamp on one side does not materially effect the lamps on the other side since the current returns to the neutral wire and maintains a circuit. When this system is properly balanced, the neutral wire carries very little current, and therefore can be smaller in diameter, thus securing greater economy.

Three-Wire System with Balancer

This system has a decided advantage over a three-wire system supplying energy by two generators in series, inasmuch as 1-200 volt generator can be employed. Between the outside mains is connected two dynamos of 100 volts each, the two machines being in series, the neutral wire being connected between these machines.

In case more lamps are operating on one side of the system than the other the voltage on the side which has the most lamps in operation tends to fall off, but is automatically maintained by the current flowing along the neutral wire to one machine running as a generator, and thereby boosting the voltage of the loaded side enough to make up for the voltage drop caused by the unbalanced conditions. The reverse will be true if the system becomes unbalanced by more lamps being operated on the other side. By carefully balancing the two sides of this system the load will not vary more than 8 or 10%, so that the capacity of the motor generator set will only be about 8 or 10% of the capacity of the main generator supplying the energy of the circuit.

In maintaining the voltage at the lamp to a fairly constant value it is necessary that the group of lamps employed be as near the point of distribution as possible and that the diameter of the wire be large enough to carry the current without a very large drop in voltage. A formula is given on page 99 for calculating the drop in voltage between the lamps and the point of distribution. The factors which determine the sizes of wire are:

First; the wire must be large enough to carry the desired current without overheating and injuring the insulation.

Second; the wire must be large enough to keep the voltage at the lamps within certain limits. A total drop of 5% is permissible: 2% in the mains and 3% in the distributing wires.

In a system where power is fed at the end of the system the lamps are arranged in parallel. In this system the voltage drop is great, inasmuch as the load center is far from the point of distribution, and the current has to traverse a large amount of copper. It is also necessary to have a wire of large diameter to prevent excessive drop.

A method for maintaining a constant voltage at the lamps but which requires more copper is the return loop system. In this system each lamp receives approximately the same voltage, inasmuch as the current to each lamp has to traverse the same amount of copper conductor. This is a great advantage in all extensive interiors, for when lamps are installed they can be selected for the same voltage and there is no fear that a lamp on the top floor of a very tall building would receive a lower voltage than on the lower floor. A system of this type installed in one of the prominent tall buildings of New York City on voltage survey showed a drop of less than 2% on a 200-volt system and the voltage was fairly constant over the entire building.

The Conversion of Two-Wire High Voltage Systems to Three-Wire Low Voltage Systems.

Due to the better performance and greater economy gained by the use of 100-130 volt lamps in preference to the 200-260 volt types it is often desirable to change a high voltage system. In such a case it is often inconvenient and not at

all practical to alter the wiring of the whole building. Recently such a change was desired in a large building in New York City. The problem here was simplified to a great extent by the plan of wiring then in use. This plan is shown in Fig. 30 and consisted of a three-wire system with

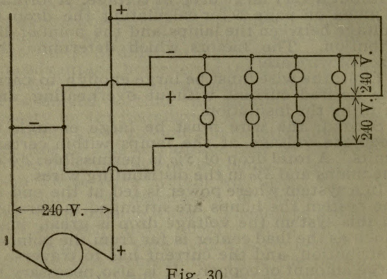


Fig. 30

the two outside wires connected to the negative bus-bar and the return loop connected to the positive, so that in reality it was a double two-wire system, having a potential of 240 volts between the positive and each of the two negative wires. This plant was changed over without altering the wiring of the building, by changing the switchboard connections in the following manner: A balancer set was installed and what was formerly the positive wire was connected to the neutral of this set. One of the outside wires was connected to the negative bus-bar and the

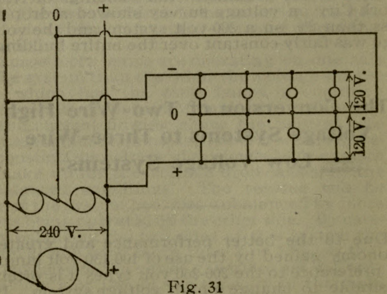


Fig. 31

other to the positive. The new connections are shown in Fig. 31. By this method 120 volt lamps can be used instead of the 240 volt types. As the load is nearly balanced, a balancer set of small capacity is used to take care of any fluctuations in either side of the line.

Distribution Systems

Direct Current

Two Wire

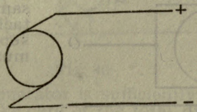


Fig. 32

Return Loop

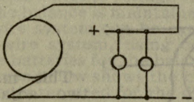


Fig. 33

Three-Wire, Two Generators

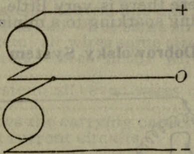


Fig. 34

Balancer Set

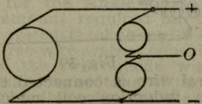


Fig. 35

Storage Battery Balancer

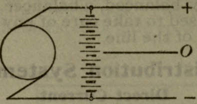
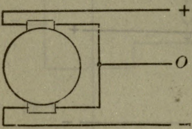


Fig. 36

Double Dynamo



Two armature windings on the same core attached to two separate commutators.

Fig. 37

Three Brush Dynamo

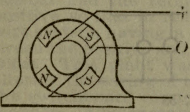


Fig. 38

This machine has two adjacent north poles and two adjacent south poles, making practically a bi-polar machine with divided poles. The neutral brush is taken off between like poles where there is very little e. m. f. generated, reducing sparking to a minimum.

Dobrowolsky System

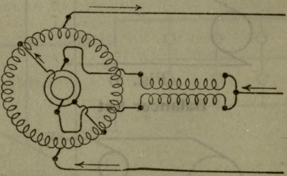


Fig. 39

The neutral wire is connected to the middle point of an induction coil which in turn is connected to two diametrically opposite points of the winding of the armature. The e. m. f.

impressed on the terminals is alternating and the inductance set up in the two halves of the coil are equal. keeping the potential of the neutral wire midway between that of the outside wires.

Three-Wire System With Compound Wound Boosters

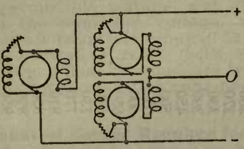


Fig. 40

The main generator is sufficiently over-compounded to take care of the total drop in the conductors. The boosters are also compound wound and mechanically coupled. An increase of current through the series field coil of either machine produces a higher voltage on the loaded side, so that the balance is maintained.

The three-wire system can be extended to a five or seven-wire system, using compensator sets or storage batteries for the balancers.

The table given below shows the comparative weights of copper required for the different systems to deliver the same wattage with the same drop in potential at the receiving end.

Ordinary two-wire system	1.000
Three-wire system; all three wires of same size	.375
Three-wire system; neutral one-half size	.313
Four-wire system; all wires same size	.222
Five-wire system; all wires same size	.156
Five-wire system; three inside wires one-half size	.109
Seven-wire system; all seven wires of same size	.097

Table 22 shows the carrying capacity of copper wire for direct current circuits.

Alternating Current Systems.

In Table 23 is shown the amount of copper required by the various systems as compared with that required for the single phase two-wire system. The amount required for the single phase two-wire system is taken as 100%. In the single phase three-wire system consider the potential between the two outside wires as $2e$, where e represents the voltage of the two-wire system. Applying the rule that the amount of copper varies inversely as the square of the voltage, only one quarter the copper will be needed,

22. Table of Current-Carrying Capacity of Copper Wire.

B & S Gauge	* Table 1 Amperes	† Table 2 Amperes	Circular Mils	Table 1 Amperes	Table 2 Amperes
18	3	5	200,000	200	300
16	6	8	300,000	270	400
14	12	16	400,000	330	500
12	17	23	500,000	390	590
10	24	32	600,000	450	680
8	33	46	700,000	500	760
6	46	65	800,000	650	840
5	54	77	900,000	600	920
4	65	92	1,000,000	650	1,000
3	76	110	1,100,000	690	1,080
2	90	131	1,200,000	730	1,150
1	107	156	1,300,000	770	1,220
0	127	185	1,400,000	810	1,290
00	150	220	1,500,000	850	1,360
000	177	262	1,600,000	890	1,430
0000	210	312	1,700,000	930	1,490
			1,800,000	970	1,550
			1,900,000	1,010	1,610
			2,000,000	1,050	1,670

* Table 1 refers to rubber covered wire.
† Table 2 refers to wire with weather-proof insulation.

and add to this a neutral of the same size as the outside wires, making a total of 37.5%. In a four-wire system the voltage between outside wires is $3\ e$, and with neutral and outside wires of equal size the amount of copper required will be 22%. The two phase, four-wire system requires 100%. The two phase three-wire system requires 145.7% when the comparison is based on the highest permissible voltage, and 72.9% when based on the minimum voltage. The three phase, three-wire system requires 33.3%. with a full sized neutral or 29.17% with the neutral one-half size. Phase relations are treated more fully under Transformer Connections on page 128.

23. Amount of Copper Required for Transmission at a Given Loss, Based on Minimum Difference of Potential.

System	No. of Wires	Per Cent Copper
Single-Phase	2	100
Single-Phase	3	37.5
Two-Phase, common return	3	72.9
Two-Phase	4	100
Three-Phase	3	75
Three-Phase, neutral full size	4	33.3
Three-Phase, one-half size	4	29.17

24. Amount of Copper Required for Transmission at a Given Loss, Based on Maximum Difference of Potential.

System	No. of Wires	Per Cent Copper
Single Phase	2	100
Two-Phase, with common return	3	145.7
Two-Phase	4	100
Three-Phase	3	75

The following general formulae may be used to determine the size of copper conductors, current per conductor, volts loss in lines, and weight of copper per circuit for alternating current distribution systems:

25. (See page 99 for application of this table).

System	Values of A	Values of K Per Cent Power Factor 100	95	85	80	Values of T Per Cent Power Factor 100	95	85	80
Single-phase	6.04	2160	2400	3000	3380	1.00	1.05	1.17	1.25
Two-phase (4 wire)	12.08	1080	1200	1500	1690	50	53	59	62
Three-phase (3 wire)	9.06	1080	1200	1500	1690	.58	.61	68	.72

VALUES OF M

No. of wire B & S or A. W. Gauge	25 Cycles Per cent Power Factor				60 Cycles Per cent Power Factor				125 Cycles Per Cent Power Factor				No. of wire B & S or A. W. Gauge
	95	90	85	80	95	90	85	80	95	90	85	80	
0000	1.23	1.29	1.33	1.34	1.62	1.84	1.99	2.09	2.35	2.86	3.24	3.49	0000
000	1.18	1.22	1.24	1.24	1.49	1.66	1.77	1.95	2.08	2.48	2.77	2.94	000
00	1.14	1.16	1.16	1.16	1.34	1.52	1.60	1.66	1.86	2.18	2.40	2.57	00
0	1.10	1.11	1.10	1.09	1.31	1.40	1.46	1.49	1.71	1.96	2.13	2.25	0
1	1 07	1.07	1 05	1.03	1.24	1.30	1.34	1.36	1.56	1.75	1.88	1.97	1
2	1.05	1.04	1.02	1.00	1.18	1.23	1.25	1.26	1.45	1.60	1.70	1.77	2
3	1.03	1.02	1.00	1.00	1.14	1.17	1.18	1.17	1.35	1.46	1.53	1.57	3
4	1.02	1.00	1.00	1.00	1.11	1.12	1.11	1.10	1.27	1.35	1.40	1.43	4
5	1.00	1.00	1.00	1.00	1.08	1.08	1.06	1.04	1.21	1.27	1.30	1.31	5
6	1.00	1.00	1.00	1.00	1.05	1.04	1.02	1.00	1.16	1.20	1.21	1.21	6
7	1.00	1.00	1.00	1.00	1.03	1.02	1.00	1.00	1.12	1.14	1.14	1.13	7
8	1.00	1.00	1.34	1.00	1.02	1.00	1.00	1.00	1.09	1.10	1.09	1.07	8
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.06	1.06	1.04	1.02	9
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.04	1.03	1.00	1.00	10

Area of conductor in circular mils $= \frac{D \times W \times K}{P \times E^2}$

Current in main conductors $= \frac{W \times T}{E}$

Volts loss in lines $= \frac{P \times E \times M}{100}$

Pounds copper required $= \frac{D^2 \times W \times K \times A}{P \times E^2 \times 1{,}000{,}000}$

W = total watts delivered.
D = distance of transmission in feet (one way).
P = Line loss in per cent of power delivered, that is, of W.
E = Voltage between main conductors at receiving end of circuit.
The values of constants K, T, M and A for alternating current are given in Table 25.
For continuous current: $K = 2160$, $T = 1$, $M = 1$
$A = 6.04$

Wiring

The following formulæ will be found sufficient for calculating the size of wire required to carry a given load with a specified allowable voltage drop.

The resistance of ordinary copper wire is equal to the length in feet divided by the area in circular mils multiplied by the resistance per mil foot, which under working conditions is 10.8 ohms,

$$\text{that is, } R = \frac{l}{A} \times 10.8 \text{ ohms} \qquad (1)$$

R = Resistance in ohms
l = Total length in ft.
A = Area in circular mils

From Ohm's Law, the loss in volts (e) in a conductor is equal to the current (I) multiplied by the resistance (R)

$$\text{that is, } e = RI \qquad (2)$$

Substituting the value of R from equation (1) in equation (2)

$$e = \frac{I \times l \times 10.8}{A} \qquad (3)$$

Expressed in words, the voltage "drop" is equal to the current times the length of the conductor times 10.8 divided by the area in circular mils.

The l in formula (3) is the length of wire measured both ways or the entire circuit, that is,

$$e = \frac{I \times 2L \times 10.8}{A} = \frac{I \times L \times 21.6}{A} \qquad (4)$$

Where L is the distance between the generating and the receiving ends. Formula (4) is used to find the drop in a line knowing the size

of wire, the current to be carried, and the distance.

If we wish to find the size of wire necessary to carry a current (I) a distance (L) with an allowable voltage drop (e), by transposing the formula,

$$A = \frac{I \times L \times 21.6}{e} \qquad (5)$$

Or to determine the current that may be carried by a wire,

$$I = \frac{A \times e}{L \times 21.6} \qquad (6)$$

If it is desired to find the size of wire required to carry a certain number of lamps, substitute for (I) the number of lamps (N) multiplied by the current taken by each lamp (i)

$$\text{or } A = \frac{N \times i \times L \times 21.6}{e} \qquad (7)$$

It is sometimes more convenient to make the calculation in terms of the wattage of the lamps used,

$$\text{then } A = \frac{W \times N \times L \times 21.6}{E \times e}$$

Where W = watts per lamp, E = circuit voltage at lamps and e is the voltage "drop."

Application of Kelvin's Law

The question of permissible voltage drop in a circuit increases in importance as the cost of energy increases. There are so many factors to be taken into consideration that it is impossible to give a complete discussion in a limited space. However, in any installation the amount of energy to be transmitted being known, it is an easy matter to find the average kilowatt hours wasted in a conductor of a given resistance. With regard to the conductors it is principally a question of additional cost of copper, as the other construction charges are not greatly affected by the increase in size of the conductors.

In calculating the size of wire to carry a given load, a simple application of Kelvin's law may be used. The most economical current density per million circular mils is

$$A\sqrt{\frac{L}{C}}$$

Where L = increase in annual charges on transmission line resulting from increasing the weight of feeders one ton, and C = increase in annual operating cost and capital charges on the power station, resulting from increasing the output one kilowatt, A is a constant whose value is

$$2170\sqrt{\frac{\text{Weight of conductors, lbs. per cu. in.}}{\text{Specific resistance, ohms. per mil foot}}}$$

For copper, A = 380
Aluminum, A = 165
To obtain the economical current density it is best to make calculation using the maximum possible value of L, also calculations using the minimum possible value of L. The mean of these calculations will give the advisable current density.

General Electric Company Mercury Arc Rectifiers.

(P. D. WAGONER)

A detailed idea of the operation of the mercury arc rectifier circuit may be obtained from Fig. 41. Assume an instant when the terminal *H* of the supply transformer is positive, the anode *A* is then positive and the arc is free to flow between *A* and *B*, *B* being the mercury cathode. Following the directions of the arrows still further the current passes through the load *J*, through the reactance coil *E* and back to the negative terminal *G* on the transformer. A little later when the impressed electromotive force falls below a value sufficient to maintain the arc against the counter electromotive force of the arc and load, the reactance *E*, which heretofore has been charging, now discharges, the discharge current being in the same direction as formerly. This serves to maintain the arc in the rectifier until the electromotive force of the supply has passed through zero, reverses and builds up to such a value as to cause *A′* to have a sufficiently positive value to start an arc between it and the mercury cathode *B*. The discharge circuit of the reactance coil *E* is now through the arc *A′B*, instead of through its former circuit. Consequently the arc *A′B* is now supplied with current, partly from the transformer and partly from the reactance coil *E*. The new circuit from the transformer is indicated by the arrows inclosed in circles. The amount of reactance inserted in the circuit reduces the pulsations of the direct current sufficiently for all ordinary commercial purposes. Where it is advisable to still further reduce the amplitude of the pulsations, as, for instance, in telephone work, this is done with very slight reduction in efficiency by means of reactances.

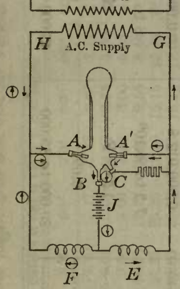


Fig. 41.

26. General Properties of Aluminum and Copper.

	Aluminum	Copper (Hard drawn)	Copper (Soft drawn)
Specific gravity	2.68	8.93	8.89
Relative specific gravity	1.00	3.33	0.995
Conductivity (Matthiessen's Standard)	61 to 63	96 to 99	99 to 102
Elastic limit, solid wire (lbs. per sq. in.)	14,000	35,000 to 40,000	3,000 to 5,000
Coefficient of expansion per degree Fahr	0,000,012,8	0,000 009,6	0,000,009,6
Modulus of elasticity, solid wire	7.5 to 9×10^6	8 to 16×10^6	....
Melting point (about)	1200° F	2000° F	2000° F
Lbs. per cu. in.	0.097	0.32	0.32
Tensile strength, solid wire lbs. per sq. in.	20,000 to 35,000	45,000 to 68,000	25,000 to 45,000

27. Table Showing Size of Wire to Use for Drop of One Volt for Various Currents and Distances.

Size (No. of Wire B. & S.)	Distance in Feet to Center of Distribution																
	20′	25′	30′	35′	40′	45′	50′	60′	70′	80′	90′	100′	120′	140′	160′	180′	200
14	9.5	7.60	6.34	5.42	4.75	4.22	3.80	3.17	2.62	2.37	2.11	1.90	1.58	1.35	1.18	1.06	95
12	15.1	12.08	10.06	8.64	7.55	6.61	6.04	5.03	4.31	3.78	3.36	3.02	2.51	2.15	1.88	1.68	1.51
10	24.0	19.20	16.00	13.60	12.00	10.66	9.60	8.00	6 86	6.00	5.33	4.80	4.00	3.43	3.00	2.66	2.40
8	33	30.55	25.45	21.80	19.10	16.90	15.28	12.72	10.90	9.55	8.49	7.64	6.36	5.45	4.77	4.24	3.82
6	46	46	40.4	34.60	30.30	26.95	24.25	20.20	17.30	15.15	13.48	12.12	10.10	8.66	7.58	6.24	6.06
5	54	54	51.0	43.75	38.25	34.00	30.60	25.50	21.85	19.12	17.00	15.30	12.75	10.92	9.56	8.50	7.65
4	65	65	64.5	55.15	48.25	42.90	38.60	32.17	27.58	24.13	21.44	19.30	16.08	13.79	12.06	10.72	9.65
3	76	76	76	69.6	60.9	54.1	48.7	40.60	34.80	30.45	27.05	24.35	20.30	17.40	15.22	13.52	12.17
2	90	90	90	87.6	76.6	68.1	61.4	51.1	43.8	38.30	34.05	30.66	25.55	21.90	19.15	17.02	15 23
1	107	107	107	107	95.5	84.9	76.4	69.5	54.6	47.75	42.45	38.20	31.85	27.30	23.86	21 22	19.10
0	127	127	127	127	122.0	108.4	97.6	81.3	69.7	61.00	54.20	48.80	40.65	34.85	30.50	27.10	24.40
00	150	150	150	150	150	136.6	123.0	102.5	87.9	76.80	68.30	61.50	51.25	43.90	38.40	34.15	30.75
000	177	177	177	177	177	172.2	155.0	129.2	110.7	96.9	86.1	77.5	64.6	55.35	48.45	43.05	38.75
0000	210	210	210	210	210	210	195.6	163.0	139.6	122.3	109.6	97.8	81.5	69.8	61.15	54.30	48.30

Formula used $A = \frac{I\ D\ 21.62}{V}$

Currents found under the broken line are the maximum allowable by National Board of Underwriters for the size specified (Rubber Covered Wire) The drop for these currents is less than one volt. This table is for continuous current only. If A. C. single phase, for lighting load, multiply values given in the table by .9; for lighting and power load, multiply the values given in the table by .82. If A. C. two phase (4 wire) or three phase (3 wire), for lighting load, multiply values given in the table by 1.8; for lighting and power load, multiply the values given in the table by 1.64.

28. TABLE OF COMPARATIVE SIZES OF WIRE GAUGES IN DECIMALS OF AN INCH.

No. of Wire Gauge	Brown & Sharpe	American Steel & Wire Co. or Washburn-Moen	Birmingham or Stubb's	English Legal Standard	Old English or London
0000000	....	0.4900	....	0.500	....
000000	0.58000	0.4615	....	0.464	....
00000	0.51650	0.4305	0.500	0.432	....
0000	0 46000	0.3938	0.454	0.400	0.454
000	0.40964	0.3625	0.425	0.372	0.425
00	0.36480	0.3310	0.380	0.348	0.380
0	0.32495	0.3065	0.340	0.324	0.340
1	0.28930	0.2830	0.300	0.300	0.300
2	0.25763	0.2625	0.284	0.276	0.284
3	0.22942	0.2437	0.259	0.252	0.259
4	0.20431	0.2253	0.238	0.232	0.238
5	0.18194	0.2070	0.220	0.212	0.220
6	0.16202	0.1920	0.203	0.192	0.203
7	0.14428	0.1770	0.180	0.176	0.180
8	0.12849	0.1620	0.165	0.160	0.165
9	0.11443	0.1483	0.148	0.144	0.148
10	0.10189	0.1350	0.134	0.128	0.134
11	0.09074	0.1205	0.120	0.116	0.120
12	0.08081	0.1055	0.109	0.104	0.109
13	0.07196	0.0915	0.095	0.092	0.095
14	0.06408	0.0800	0.083	0.080	0.083
15	0.05706	0.0720	0.072	0.072	0.072
16	0.05082	0.0625	0.065	0.064	0.065
17	0.04525	0.0540	0.058	0.056	0.058
18	0.04030	0.0475	0.049	0.048	0.049
19	0.03589	0.0410	0.042	0.040	0.040
20	0.03196	0.0348	0.035	0.036	0.035
21	0.02846	0.0317	0.032	0.032	0.0315
22	0.02535	0.0286	0.028	0.028	0.0295
23	0.02257	0.0258	0.025	0.024	0.0270
24	0.02010	0.0230	0.022	0.022	0.0250
25	0.01790	0.0204	0.020	0.020	0.0230
26	0.01594	0.0181	0.018	0.018	0.0205
27	0.01420	0.0173	0.016	0.0164	0.01875
28	0.01264	0.0182	0.014	0.0148	0.01650
29	0.01126	0.0150	0.013	0.0136	0.00155
30	0.01003	0.0140	0.012	0.0124	0.01375
31	0.00893	0.0132	0.010	0.0116	0.01225
32	0.00795	0.0128	0.009	0.0108	0.01125
33	0.00708	0.0118	0.008	0.0100	0.01025
34	0.00630	0.0104	0.007	0.0092	0.00950
35	0.00561	0.0095	0.005	0.0084	0.00900
36	0.00500	0.0090	0.004	0.0076	0.00750
37	0.00445	0.0085	....	0.0068	0.00650
38	0.00396	0.0080	....	0.0060	0.00575
39	0.00353	0.0075	....	0.0052	0.00500
40	0.00314	0.0070	....	0.0048	0.00450

The Edison Gauge is the area in circular mils divided by 1000.

29. Birmingham or Stubb's Wire Gauge.

B. W. G. Stubb's	Diameter Inches	AREA Circular Mils	AREA Square Mils	Lbs. per foot copper
0000	0.454	206,100	161,883	0.6239
000	0.425	180,600	141,863	0.5468
00	0.380	144,400	113,411	0.4371
0	0.340	115,600	90,792	0.3499
1	0.3000	90,000	70,686	0.2724
2	0.2840	80,660	63,347	0.2441
3	0.2590	67,080	52,685	0.2031
4	0.2380	56,640	44,488	0.1715
5	0.2200	48,400	38,013	0.1465
6	0.2030	41,210	32,365	0.1247
7	0.1800	32,400	25,447	0.09808
8	0.1650	27,230	21,382	0.08241
9	0.1480	21,900	17,203	0.06630
10	0.1340	17,960	14,103	0.05435
11	0.1200	14,400	11,310	0.04359
12	0.1090	11,880	9,331	0.03596
13	0.0950	9,025	7,088	0.02732
14	0.0830	6,889	5,411	0.02085
15	0.0720	5.184	4,072	0.01569
16	0.0650	4,225	3,318	0.01279
17	0.0580	3,364	2,642	0.01018
18	0.0490	2,401	1,886	0.007268
19	0.0420	1,764	1,385	0.005340
20	0.0350	1,225	962	0.003708

30. SOLID WIRES

Rating of Wires. American or Brown & Sharpe Gauge.

A. W. G. B. & S.	Diameter, Inches	Area		Copper		Aluminum	
		Circular Mils	Square Mils	Lbs. per Foot	Feet per Lb.	Lbs. per Foot	Feet per Lb.
0000	0.460	211,600	166,190	0.6405	1.561	0.1929	5.185
000	0.4096	167,800	131,790	0.5080	1.969	0.1529	6.539
00	0.3648	133,100	104.518	0.4028	2.482	0.1213	8.246
0	0.3249	105 500	82,887	0.3195	3.130	0.09618	10.40
1	0.2893	83,690	65,732	0.2533	3.947	0.07629	13.11
2	0.2576	66,370	52,128	0.2009	4.977	0.06050	16.53
3	0.2294	52,630	41,339	0.1593	6.276	0.04797	20.85
4	0.2043	41,740	32,784	0.1264	7.914	0.03805	26.28
5	0.1819	33,100	25,999	0.1002	9.980	0.03017	33.15
6	0.1620	26,250	20,618	0.07946	12.58	0.02393	41.79
7	0.1443	20,820	16,351	0.06302	15.87	0.01898	52.69
8	0.1285	16,510	12,967	0.04998	20.01	0.01505	44.66

30. SOLID WIRES

Rating of Wires. American or Brown & Sharpe Gauge.

(Continued)

A. W. G. B. & S.	Diameter, Inches	Area		Copper		Aluminum	
		Circular Mils	Square Mils	Lbs. per Foot	Feet per Lb.	Lbs. per Foot	Feet per Lb.
9	0.1144	13,090	10,283	0.03963	25.23	0.01193	83.82
10	0.1019	10,380	8,155	0.03143	31.82	0.009462	105.7
11	0.09074	8,234	6,467	0.02493	40.12	0.007505	133.2
12	0.08081	6,530	5,129	0.01977	50.59	0.005952	168.0
13	0.07196	5,178	4,067	0.01568	63.79	0.004720	211.9
14	0.06408	4,107	3,225	0.01243	80.44	0.003743	267.2
15	0.05707	3,257	2,558	0.009858	101.4	0.002968	336.9
16	0.05082	2,583	2,029	0.007818	127.9	0.002354	424.8
17	0.04526	2,048	1,609	0.006200	161.3	0.001867	535.6
18	0.04030	1,624	1,276	0.004917	203.4	0.001480	675.7
19	0.03589	1,288	1,012	0.003899	256.5	0.001174	851.8
20	0.03196	1,022	802	0.003092	323.4	0.000930	1074.1

Watt-Hour Meters

The Watt-hour meters on the market at the present time are, in the main, of two general types, the induction type and the Thomson or motor type. There are several makes including meters for various conditions of service, but the majority are an adaptation of one or the other of these two types. With this in mind, a brief discussion is given herewith on the theory of each type.

The Induction Watt-hour Meter is suitable for alternating current circuits only. In this meter a tri-polar magnet of laminated iron exerts a driving torque on an aluminum disc. The two positive lugs L_1 L_1 of the magnet are wound with coarse wire to carry the line current, and the middle lug L_2 is wound with fine wire, which is connected across the main as shown in Fig. 42.

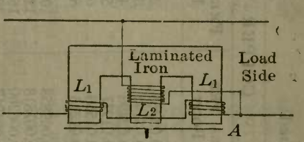


Fig. 42

As before stated, this meter is used on alternating current circuits. The surging of the current back and forth through the coils of L_1 L_1 sets up a changing flux in the lugs, producing in turn a surging current through the disc under L_2. This in turn sets up a changing flux in L_2, producing an electro-motive-force equal to the line voltage at each instant. Furthermore, this flux induces a proportional electro-motive-force about L_2 in the disc. A current is set up in the disc in the direction of the induced electro-motive-force and proportional to the line voltage at each instant. This current flowing under L_1 L_1 causes the flux under them to exert a torque on the disc which is proportional at each instant to both line current and the line voltage, so that the driving torque is at each instant proportional to the load delivered to the receiving circuit. The motion of the disc is damped by permanent magnets so that the speed is proportional to the driving torque. The total work delivered to the receiving circuit is registered on the dials which are driven by the spindle on which the disc is mounted.

The Thomson Watt-hour Meter can be used on either direct or alternating current lines. This meter (Fig. 43) is a small electric motor without iron parts. The field coils carry the line

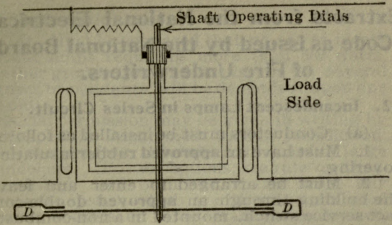


Fig. 43

current and the armature is connected across the line. The speed of reduction is damped by the electro-magnetic drag upon the copper disc caused by the permanent magnets DD. The driving torque exerted upon the armature is proportional at each instant to the current both in the field coils and in the armature, that is, it is proportional both to the line current and to the line voltage. The damping force exerted on the disc by the magnets is proportional to the speed, so that the total number of revolutions on the dials is always proportional to the watt-hours of work delivered to the receiving circuit.

Extracts from the National Electrical Code as issued by the National Board of Fire Underwriters.

22. Incandescent Lamps in Series Circuit.

(a) Conductors must be installed as follows:

1. Must have an **approved** rubber insulating covering.

2. Must be arranged to enter and leave the building through an **approved** double-contact service switch, mounted in a non-combustible case, kept free from moisture, and easy of access to police or firemen.

3. Must always be in plain sight, and never encased, except when **required** by the Inspection Department having jurisdiction.

4. Must be supported on glass or porcelain insulators, which separate the wire at least one inch from the surface wired over and must be kept **rigidly** at least eight inches from each other, except within the structure of lamps, on hanger-boards or in cut-out boxes, or like places, where a less distance is necessary.

5. Must, on side walls, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness. Instead of the running-boards, guard strips on each side of and close to to the wires will be accepted, These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

(b) Each lamp must be provided with an automatic cut-out.

(c) Each lamp must be suspended from a hanger-board by means of rigid tube. Hanger-board (73) must be so constructed that all wires and current-carrying devices thereon will be exposed to view and thoroughly insulated by being mounted on a non-combustible non-absorptive insulating substance. All switches attached to the same must be so constructed that they shall be automatic in their action, cutting off both poles to the lamp, not stopping between points when started and preventing an arc between points under all circumstances.

(d) No electro-magnetic device for switches and no multiple-series or series-multiple system of lighting will be approved.

(e) Must not under any circumstances be attached to gas fixtures.

23. Automatic Cut-outs.

(d) Must be so placed that no set of incandescent lamps, requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent upon one cut-out.

Special permission may be given in writing by the Inspection Department having jurisdiction, for departure from this rule, in the case of large chandeliers. (For exceptions, see rule on theater wiring). All branches or taps from any three-wire system which are directly connected to lamp sockets or other translating devices, must be run as two-wire circuits, if the fuses are omitted in the neutral, or if the difference of potential between the two outside wires is over 250 volts, and both wires of such branch or tap circuits must be protected by proper fuses.

25. Electric Heaters.

It is often desirable to connect in multiple with the heaters and between the heater and the switch controlling same, an incandescent lamp of low candle-power, as it shows at a glance whether or not the switch is open, and tends to prevent its being left closed through oversight.

(a) Must be protected by a cut-out and controlled by indicating switches. Switches must be double pole except when the device controlled does not require more than 660 watts of energy.

(b) Must never be concealed, but must at all times be in plain sight. Special permission may be given in writing by the Inspection Department having jurisdiction for departure from this rule.

(c) Flexible conductors for smoothing irons and sad irons, and for all devices requiring over 250 watts must have an **approved** insulation and covering.

(d) For portable heating devices the flexible conductors must be connected to an **approved** plug device, so arranged that the plug will pull out and open the circuit in case any abnormal strain is put on the flexible conductor. This device may be stationary, or it may be placed in the cord itself. The cable or cord must be attached to the heating apparatus in such manner that it will be protected from kinking, chafing or like injury at or near the point of connection.

(e) Smoothing irons, sad irons and other heating appliances that are intended to be applied to inflammable articles, such as clothing, must conform to the above rules so far as they apply. They must also be provided with an approved stand, on which they should be placed when not in use.

(f) Stationary electric heating apparatus,

such as radiators, ranges, plate warmers, etc., must be placed in a safe location, isolated from inflammable materials, and be treated as sources of heat.

Devices of this description will often require a suitable heat-resisting material placed between the device and its surroundings. Such protection may best be secured by installing two or more plates of tin or sheet steel with a one-inch air space between or by alternate layers of sheet steel and asbestos with a similar air space.

(g) Must each be provided with name-plate, giving the maker's name and the normal capacity in volts and amperes.

31. Sockets.

(For construction of Sockets see No. 72).

(a) In rooms where inflammable gases may exist, the incandescent lamp and socket must be enclosed in a vapor-tight globe and supported on a pipe-hanger, wired with **approved** rubber-covered wire soldered directly to the circuit.

(b) In damp or wet places "waterproof" sockets must be used. Unless made upon fixtures they must be hung by separate **stranded** rubber-covered wires not smaller than No. 14 B & S gauge, which should preferably be twisted together when the pendant is over three feet long.

These wires must be soldered directly to the circuit wires but supported independently of them.

(c) Key sockets will not be approved if installed over specially inflammable stuff, or where exposed to flyings of combustible material.

Flexible Cord.

(For construction of Flexible Cord see No. 54).

(a) Must have an approved insulation and covering.

(b) Must not, except in street railway property, be used where the difference of potential between the two wires is over 300 volts.

(c) Must not be used as a support for clusters.

(d) Must not be used except for pendants, wiring of fixtures, portable lamps or motors, and portable heating apparatus.

For all portable work, including those pendants which are liable to be moved about sufficiently to come in contact with surrounding objects, flexible wires and cables especially designed to withstand this severe service must be used.

When necessary to prevent portable lamps from coming in contact with inflammable materials, or to protect them from breakage, they must be surrounded with a substantial wire guard.

(e) Must not be used in show windows or

show cases except when provided with an **approved** metal armor.

(f) Must be protected by insulating bushings where the cord enters the socket.

(g) Must be so suspended that the entire weight of the socket and lamp will be borne by some **approved** method under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

37. Decorative Lighting Systems.

Special permission may be given in writing by the Inspection Department having jurisdiction for the temporary installation of **approved** Systems of Decorative Lighting, provided the difference of potential between the wires of any circuit shall not be over 150 volts and also provided that no group of lamps requiring more than 1,320 watts shall be dependent on one cut-out.

71. Rosettes.

Ceiling rosettes, both fused and fuseless, must be constructed in accordance with the following specifications:—

(a) **Base.**

Current carrying parts must be mounted on non-combustible, non-absorptive, insulating bases. There should be no openings through the rosette base except those for the supporting screws and in the concealed type for the conductors also, and these openings should not be made any larger than necessary.

There must be at least one-fourth inch space, measured over the surface, between supporting screws and current-carrying parts. The supporting screws must be so located or countersunk that the flexible cord cannot come in contact with them.

Bases for the knob and cleat type must have at least two holes for supporting screws; must be high enough to keep the wires and terminals at least one-half inch from the surface to which the rosette is attached, and must have a porcelain lug under each terminal to prevent the rosette from being placed over projections which would reduce the separation to less than one-half inch.

Bases for the moulding and conduit box types must be high enough to keep the wires and terminals at least three-eighths of an inch from the surface wired over.

(b) Mounting.

Contact pieces and terminals must be secured in position by at least two screws, or made with a square shoulder, or otherwise arranged to prevent turning.

The nuts or screw heads on the under-side of

the base must be countersunk not less than one-eighth of an inch and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit (65 degrees Centigrade).

72. Sockets.

(For installation rules see No. 31.)

(b) **Ratings.**

Key Sockets.—The standard key socket (any socket having Standard Edison screw shell and ordinary "slow make" switch) to be rated 250 watts, 250 volts.

Marking may be 250 W,, 250 V. This rating shall not be interpreted to permit the use, at any voltage, of current above 2½ amperes on any standard key or pull socket.

A key socket with Standard Edison shell and special switch which "makes" and "breaks" with a quick snap and does not stop when motion has been once imparted by the button or handle may be rated 660 watts, 250 volts (660 W., 250 V.).

Miniature and Candelabra key sockets to be rated 75 watts, 125 volts (75 W., 125 V.).

Keyless Sockets.—Standard keyless sockets with Standard Edison screw shell to be rated 660 watts, 250 volts (660 W., 250 V.). This rating shall not be interpreted to permit the use, at any voltage, of current above 6 amperes on any keyless socket.

Weatherproof sockets with Standard Edison shell and having no exposed current carrying parts may be rated 660 watts, 600 volts (600 W., 600 V.).

Minature and candelabra keyless sockets to be rated 75 watts, 125 volts (75 W., 125 V.).

Double Ended Sockets.—Each Edison screw shell to be rated at 250 watts, 250 volts for key type, 660 watts, 250 volts for keyless type, the devices being marked with a single marking applying to each lamp holder.

These ratings shall not be interpreted to permit the use, at any voltage, of current above 2½ amperes for key type, or above 6 amperes for keyless types.

(g) **Spacing.**

Points of opposite polarity must everywhere be kept not less than three sixty-fourths of an inch apart, unless separated by a reliable insulation.

(h) **Connections.**

The connecting points for the flexible cord must be made to very securely grip a No. 16 or 18 B. & S. gauge conductor. An up-turned lug, arranged so that the cord may be gripped between the screw and the lug in such a way that it cannot possibly come out is strongly advised.

(i) **Lamp Holder.**

The socket must firmly hold the lamp in

place so that it cannot be easily jarred out and must provide a contact good enough to prevent undue heating with the maximum current allowed. The holding pieces, spring and the like, if a part of the circuit, must not be sufficiently exposed to allow them to be brought in contact with anything outside of the lamp and socket.

(j) **Base.**

The base on which current carrying parts are mounted must be of porcelain and all insulating material used must be of approved material.

(k) **Key.**

The socket key-handle must be of such a material that it will not soften from the heat of a fifty candle-power lamp hanging downwards from the socket in air at 70 degrees Fahrenheit (21 degrees Centigrade), and must be securely, but not necessarily rigidly attached to the metal spindle which it is designed to turn.

(l) **Sealing.**

All screws in porcelain pieces which can be firmly sealed in place, must be so sealed by a waterproof compound which will not melt below 200 degrees Fahrenheit (93 degrees Centigrade).

(m) **Putting Together.**

The socket as a whole must be so put together so that it will not rattle to pieces. Bayonet joints or an equivalent are recommended.

(o) **Keyless Sockets.**

Keyless sockets of all kinds must comply with the requirements for key sockets as far as they apply.

(p) **Sockets of Insulating Material.**

Sockets made of porcelain or other insulating material must conform to the above requirements as far as they apply, and all parts must be strong enough to withstand a moderate amount of hard usage without breaking.

Porcelain shell sockets being subject to breakage and constituting a hazard when broken, will not be accepted for use in places where they would be exposed to hard usage.

(q) **Inlet Bushing.**

When the socket is not attached to a fixture, the threaded inlet must be provided with a strong insulating bushing having a **smooth** hole at least nine thirty-seconds of an inch in diameter. The edges of the bushing must be rounded and all inside fins removed, so that in no place will the cord be subjected to the cutting or wearing action of a sharp edge.

Bushings for sockets having an outlet threaded for three-eighths inch pipe should have a hole thirteen thirty-seconds of an inch in diameter, so that they will accommodate **approved** reinforced flexible cord.

STANDARD SYMBOLS FOR WIRING PLANS

AS ADOPTED AND RECOMMENDED BY

THE NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION OF THE UNITED STATES AND THE AMERICAN INSTITUTE OF ARCHITECTS

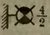
Copies may be had on application to the Sec'y of The Nat. Elec. Cont. Assoc'n. Utica, N.Y. and the Sec'y of The American Instit. of Architects, Washington, D.C.

 Ceiling Outlet; Electric only. Numeral in center indicates number of Standard 16 C.P. Incandescent Lamps.

 Ceiling Outlet; Combination. $\frac{4}{2}$ indicates 4-16 C.P. Standard Incandescent Lamps and 2 Gas Burners.

 If gas only.

 Bracket Outlet; Electric only. Numeral in center indicates number of Standard 16 C.P. Incandescent Lamps.

 Bracket Outlet; Combination. $\frac{4}{2}$ indicates 4-16 C.P. Standard Incandescent Lamps and 2 Gas Burners.

 If gas only.

 Wall or Baseboard Receptacle Outlet. Numeral in center indicates number of Standard 16 C.P. Incandescent Lamps.

 Floor Outlet Numeral in center indicates number of Standard 16 C.P. Incandescent Lamps.

 Outlet for Outdoor Standard or Pedestal; Electric only. Numeral indicates number of Standard 16 C.P. Lamps.

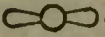
 Outlet for Outdoor Standard or Pedestal; Combination $\frac{6}{6}$ indicates 6-16 C.P. Standard Incan. Lamps; 6 Gas Burners.

 Drop Cord Outlet.

 One Light Outlet, for Lamp Receptacle.

 Arc Lamp Outlet.

 Special Outlet, for Lighting, Heating and Power Current, as described in Specifications.

 Ceiling Fan Outlet.

S^1 S. P. Switch Outlet.

S^2 D. P. Switch Outlet.

S^3 3-Way Switch Outlet.

S^4 4-Way Switch Outlet.

S^D Automatic Door Switch Outlet.

S^E Electrolier Switch Outlet.

Show as many Symbols as there are Switches. Or in case of a very large group of Switches, indicate number of Switches by a Roman numeral, thus: S^1 XII, meaning 12 Single Pole Switches. Describe Type of Switch in Specifications, that is, Flush or Surface, Push Button or Snap.

 Meter Outlet.

 Distribution Panel.

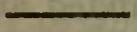
 Junction or Pull Box.

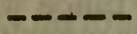
 Motor Outlet; Numeral in center indicatee Horse Power.

 Motor Control Outlet.

 Transformer.

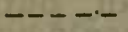
 Main or Feeder run concealed under Floor.

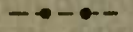
 Main or Feeder run concealed under Floor above.

 Main or Feeder run exposed.

 Branch Circuit run concealed under Floor.

 Branch Circuit run concealed under Floor above.

 Branch Circuit run exposed.

 Pole Line.

 Riser.

 Telephone Outlet; Private Service.

 Telephone Outlet; Public Service.

 Bell Outlet.

 Buzzer Outlet.

 Push Button Outlet; Numeral indicates number of Pushes.

 Annunciator; Numeral indicates number of Points.

 Speaking Tube.

 Watchman Clock Outlet.

 Watchman Station Outlet.

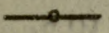
 Master Time Clock Outlet.

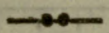
 Secondary Time Clock Outlet.

 Door Opener.

 Special Outlet, for Signal Systems, as described in Specifications.

 Battery Outlet.

 Circuit for Clock, Telephone, Bell or other Service, run under Floor, concealed.
Kind of Service wanted ascertained by Symbol to which line connects.

 Circuit for Clock, Telephone, Bell or other Service, run under Floor, above concealed.
Kind of Service wanted ascertained by Symbol to which line connects.

NOTE: If other than Standard 16 C.P. Incandescent lamps are desired, Specifications should describe capacity of Lamp to be used.

SUGGESTIONS IN CONNECTION WITH STANDARD SYMBOLS FOR WIRING PLANS.

It is important that ample space be allowed for the installation of mains, feeders, branches and distribution panels.

It is desirable that a key to the symbols used accompany all plans

If mains, feeders, branches and distribution panels are shown on the plans, it is desirable that they be designated by letters or numbers.

Heights of Centre of Wall Outlets (unless otherwise specified)

Living Rooms	5′ 6″
Chambers	5′ 0″
Offices	6′ 0″
Corridors	6′ 3″

Height of Switches (unless otherwise specified) 4′ 0″

Storage Batteries

Principal Uses

1. For propelling electrically driven motor cars.
2. For ignition for gasolene motors.
3. For railway train lighting.
4. For telephone and telegraph work.
5. To carry the load peak on a supply system.
6. To carry the entire load during the periods of light demand, the generating equipment being shut down.
7. To regulate the load on systems where the demand fluctuates widely.
8. To act as an equalizer on three-wire systems in which the generators are connected across the outsides of the system and give a corresponding voltage.
9. To reduce the amount of copper required for systems supplying variable loads.
10. To insure continuous service.
11. As auxiliaries to exciter dynamos in the large alternating current stations.
12. Combination of above uses from 4 to 8.

Lead Plate Battery

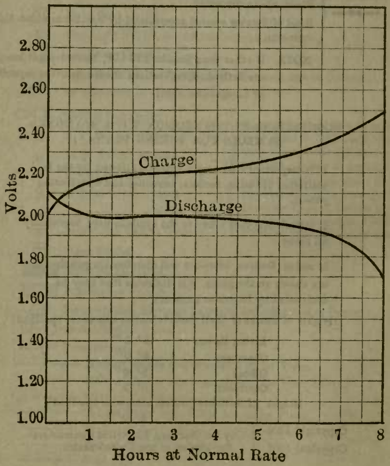


Fig. 44

The lead plate storage battery is the type now in almost general use. The negative plate is composed of lead sponge, supported by a grid of pure lead, and the positive plate consists of lead peroxide supported in a similar manner. The electrolyte is composed of dilute sulphuric acid made of sulphur and not from pyrites ($Fe\ S_2$). It need not be chemically pure but must be free from chlorine, nitrates, copper, mercury, arsenic, acetic acid and platinum. The specific gravity is generally specified by the maker of the cell, but should not be less than 1.150. The chemical changes taking place when discharging are, reading forward:—

(1) $PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O$
(2) $Pb + H_2SO_4 = PbSO_4 + H_2$
(3) $(1) + (2) = PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$

When reversed, these equations show the changes occurring when the battery is charged. The lead sulphate which is formed on both plates is a non-conductor, and if the cell is discharged to a voltage of 1.8 per cell it is extremely difficult to charge the cell again, due to the coating of lead sulphate on the grids. An over discharge increases the volume of the plates to such an extent that strains are set up causing them to buckle, or causing the active materials to crack and fall away. When fully charged the voltage per cell is about 2.5.

The capacity of a storage battery is measured in ampere hours. The charge and discharge rate varies from 6 to 10 amperes per square foot of positive surface, not taking into account the additional area obtained by ribbing or scoring. A cell of any capacity can be obtained by assembling a number of plates in parallel. All electric connections must be made by lead burning.

The efficiency is the ratio of the output to the input necessary to bring the cell back to its original condition after discharge. The efficiency of a battery used to float on a line is about 90 to 92%, and that of a battery used independently is about 75 to 80%.

Rules for Operation

These rules or precautions regarding the use of storage batteries are taken from McGraw's Standard Handbook:

1. "Be sure that the **electrolyte** is free from injurious **impurities**.

2. "Keep **electrolyte** well above tops of **plates**.

3. "Maintain the **specific gravity** of the electrolyte at the density specified by the manufacturers of the battery.

4. "Do not let the **density** of the electrolyte in any cell differ from the standard density more than 0.05. Thus a cell having normal density of 1.200 must not register above 1.205 nor below

1.195 when fully charged. Test each cell with hydrometer once a week at least.

5. "Keep **cells cleaned** out and remove sediment when it has deposited metal near the lower edges of the plates.

6. "Be sure **separators** are all in place and in good order.

7. "Note any evidence of **tank leakage** and correct at once.

8. "Maintain **insulation** of cells from ground and from each other.

9. "Begin **charge immediately** after the end of discharge or as soon thereafter as practicable.

10. "**Do not continue charge after** the negative plates begin to give off gas, except the occasional "boiling" to be mentioned in (14).

11. "**Never let charging current** fall below the 8-hour rate except toward the end of charge.

12. "**Stop discharge when** the battery potential falls to 1.75 volts per cell with the normal current; 1.70 volts per cell discharging at the 4-hour, or 1.60 volts per cell discharging at the 1-hour rate.

13. "Watch the **colors of the plates and if** they begin to grow lighter treat at once for removal of sulphate.

14. "Give the battery a **prolonged over-charge about once a month.** This over-charge should continue at about 60 per cent of the 8-hour rate until free gassing of the negative plates has continued for one hour.

15. "Never let the **battery temperature** rise above 110 deg. F and, if possible, keep below 100 deg. F.

16. "**Test each cell once a week with a cadmium electrode** and a low reading voltmeter to determine the condition of the negative plates.

17. "**Test** the cells **occasionally for drop on discharge**; excessive drop indicates the presence of sulphate, and if the drop increases the amount of sulphation is also increasing.

18. "**When one of a series of cells is sulphated,** charge it as usual in series with the others; on discharge cut the cell out, connecting the opened circuit by a heavy wire joining the two cells adjacent to the sulphated one. Be careful not to short-circuit the latter cell. When discharge is ended, remove connector and switch in the sulphated cell so that it again receives charge. Repeat this process until the cell has had its sulphate fully reduced. A double-pole, double-throw switch is conveniently used to switch the cell and the connector alternately into and out of the circuit. With it the cell may be allowed to discharge a short time before cutting out, which improves the treatment.

19. "**Cells which stand a considerable time unused**—say, as long as 45 days—should work in low density electrolyte not exceeding 1.210 specific gravity and be overcharged as directed (18).

It is better to give them a slight discharge and charge about once a week if practicable.

20. "**Cells which are to be idle two months or more** should be taken out of commission by first fully charging and then discharging for two hours at the normal rate. Then draw off the electrolyte and fill the cells with pure water, preferably distilled. Begin discharge again at the normal rate. The cells will have to be practically short-circuited to produce this discharge in the water. When the discharge has been carried to a point at which the voltage is about 0.5 volt per cell, the water is poured out of the jars and the plates washed thoroughly by putting a hose in the jar and flowing the water over the plates. Allow the water which fills the jars at the end of the washing to remain 24 hours, then pour out and allow the electrodes to dry. When the battery is to be used again, pour in electrolyte and give a prolonged overcharge."

Edison Storage Batteries

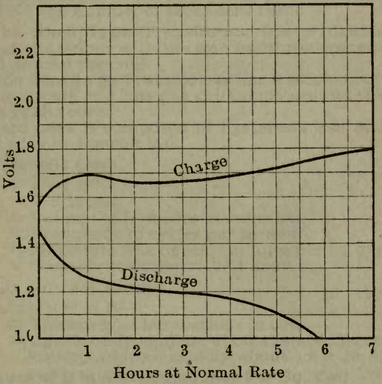


Fig. 45

The positive plate consists of one or more perforated steel tubes, heavily nickel-plated, filled with alternate layers of nickel hydroxide and pure metallic nickel in excessively thin flakes. These tubes are supported in a grid made of nickel-plated cold rolled steel. The negative plate consists of a grid of nickel-plated cold steel holding a number of rectangular pockets, filled with powdered iron oxide. The plates are insulated from each other and from the containing

jar, which is of cold rolled sheet steel, by sheets of hard rubber. The electrolyte consists of a 21% solution of potash and distilled water, with a small per cent. of lithia. The voltage per cell at normal rate of discharge is 1.2, and the charging voltage should be 1.85 volts per cell. The efficiency of the Edison cell ranges from 60 to 65%.

There are very few rules regarding the operation of the Edison cell, The steel containers should be kept dry and clean. The plates should be kept covered by the electrolyte. Best results are obtained by charging at a temperature of 75 to 85 degrees F, and discharging at 120 to 125 degrees F.

Transformers

A Transformer is a device for "stepping up" or "stepping down" the voltage of an alternating current circuit. The essential parts consist of two coils, or a multiple of two, wound upon an iron core. An alternating e. m. f. is applied to the terminals of one coil, termed the primary. See Fig, 47. The alternating current in the primary winding sets up an alternating magnetic field in the iron core. This alternating flux, cutting the secondary winding, induces an alternating e. m. f. in this winding. The relation between the primary and secondary voltages depends upon the number of turns in the secondary as compared with those in the primary winding. This relation can be expressed as follows:

$$\frac{E'}{E''} = \frac{N'}{N''},$$

Where E' is the primary voltage, E'' the secondary voltage, N' the number of primary turns and N'' the number of secondary turns.

The **Shell Type** Transformer has a double magnetic circuit with the iron built up through, and around the coils.

The **Core Type** Transformer has a single magnetic circuit and has the coils built around the legs of the core.

Core Loss is composed of hysteresis loss and the eddy or Foucalt loss.

Hysteresis Loss

$Wh = n\, V\, f\, B^{1.6} \times 10^{-7}$
Wh = Watts loss
V = Volume of iron core in cubic cm.
f = Frequency in cycles per second
B = Maximum flux density in lines per sq. cm.
n = Variable constant = .0021 approx.

Eddy Current Losses

$We = b\, V\, f^2\, t^2\, B^2$
t = Thickness of laminations in cm.
b = Constant depending upon the specific resistance of iron, usually about 1.6×10^{-11}

Values of B in Maximum Lines Per Sq. Cm.

Frequency	1–5 kw.	10–25 kw.	100–500 kw.
25	7500	6500	5500
40	6500	6500	4500
60	5000	4500	4000
100	4000	3500	3000
120	3500	3000	2500

Copper losses are composed of the I^2R losses in the primary and secondary coils. The efficiency of a transformer is the ratio of its net power output to its gross input, the output being measured with non-inductive load. The

power input is the sum of the output, the core loss and the I^2R loss of the primary and secondary coils.

Regulation in transformers is the percentage of fall in secondary voltage from no load to full load for constant potential working. Due to the increase of resistance the regulation increases with rise of temperature.

Transformer Testing for Central Stations

The financial success or failure of a lighting or power plant is dependent on the efficiency of the system. In alternating current distribution the transformers are frequently scattered in large numbers throughout the system and their cumulative losses greatly effect the efficiency of the entire system. It is therefore essential to the self-protection of Central Stations that sufficient tests are made on the transformers to be sure that the guarantees are fulfilled. The following tests can be made without a great outlay for instruments.

Insulation Test

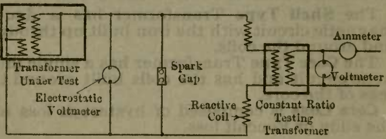


Fig. 46.

1. Between primary and all other parts.
2. Between secondary and all other parts.
3. Between turns and sections of the windings.

The method of connection is shown in Fig. 46. In applying the high potential test to one winding the remaining winding should be carefully grounded to the core and frame to avoid statically induced strains. All primary leads should be connected together as well as secondary leads, in order to secure throughout the winding a uniform potential strain during the test.

1. Set the spark gap for a voltage 10 per cent. in excess of that which is to be applied. (See Table 31).
2. By means of the regulator on the low voltage side adjust the testing outfit to deliver minimum voltage.
3. Connect the apparatus to be tested to the high voltage side of the testing outfit.
4. Close low voltage switch and gradually increase the voltage until the desired potential is indicated on the electrostatic voltmeter.
5. Reduce the voltage slowly.

If the insulation under test be good there will be no difficulty in bringing the potential up to the desired value, provided the transformer be of sufficient capacity. If, however, the insulation be weak or defective it will be impossible to obtain a high voltage, and an excessive current will be indicated by the ammeter. A breakdown in insulation will result in a drop in voltage indicated by the electrostatic voltmeter and by an excessive current.

31. Standard Spark Gap

Voltage in Kilovolts	Gap in Inches
5	.2
10	.5
20	1.0
30	1.65
40	2.50
50	3.50
60	4.60
70	5.85
80	7.10
90	8.35
100	9.50
110	10.70
120	11.85
130	12.98
140	14.00
150	15.00

Core Loss

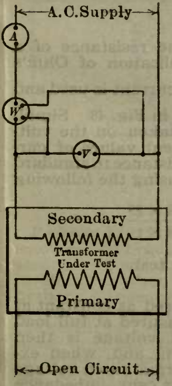


Fig. 47.

1. Estimate the capacity of the instruments required.

2. Connect the selected instruments as shown in Fig. 47 to the low potential side of transformer on test, the high potential side being on open circuit. The generator speed should be observed by a tachometer or speed counter in case a frequency meter is not available.

3. Connect leads from the transformer on test to the leads from the switchboard or source of power through a double pole, single throw switch.

4. Close the switch and make a preliminary reading of the instruments at approximately the voltage and frequency required.

5. Adjust the voltage and frequency of the circuit as desired and make simultaneous observations of the wattmeter, voltmeter, ammeter and frequency meter.

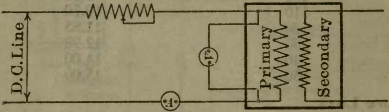
6. Record the results and note the numbers of the instruments used with their corresponding constants.

NOTE: The generator should carry no other load during the test.

7. Calculate the losses in the voltmeter and in the pressure coil of the wattmeter and subtract them from the observed reading of the wattmeter. The result is the core loss of the transformer.

NOTE: The loss in the voltmeter and in the pressure coil of the wattmeter are equal in each case to $\frac{E^2}{R}$, R being the resistance of the coil in question.

Measurement of Resistance



Transformer under Test

Fig. 48

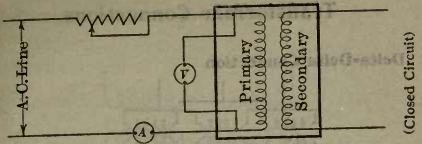
This method of finding the resistance of a transformer is simply an application of Ohm's Law, that is, $R = \frac{E}{I}$. Direct current is used and the connections are as shown in Fig. 48. Simultaneous readings should be taken on the voltmeter and ammeter at different values of current. Reduce the value of resistance to standard room temperature of 25° C. using the following equation:

$$\text{Resistance at } 25^\circ \text{ C.} = R \frac{238 \times 25}{238 \times t}$$

R = resistance at t° C.
t = temp. of transformer on test,

Impedance Loss

Impedance may be considered as constant at all loads. It is generally measured at full load current, and the impressed voltage is then known as the impedance volts, and, when expressed in per cent. of the normal rated voltage of the transformer, as the per cent. impedance drop.



Transformer under Test

Fig. 49

Connections should be as in Fig. 49.

1. Short circuit one of the windings of the transformer, preferably the secondary.
2. Adjust the voltage to give full load current in the winding of the transformer; then make simultaneous readings of the voltmeter, ammeter and frequency meter.

Record the results and calculate the impedance. In the equation,

$$I = \frac{E}{\sqrt{R^2 + (2\pi n L)^2}}$$

the expression $\sqrt{R^2 + (2\pi n L)^2}$ is the impedance in ohms.

Polarity

When transformers manufactured by different companies are to be run in parallel, it is necessary to test them in order to avoid the possibility of connecting them in such a way as to short-circuit the one on the other.

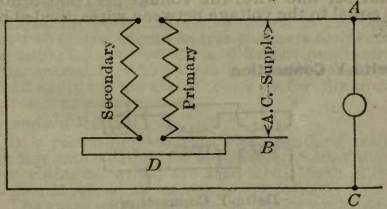
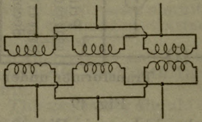


Fig. 50

Refer to Fig. 50. In the connections shown the leads are so brought out that the primary and secondary form a continuous winding, uniform in direction when B and D are connected together. Consequently, if with B and D connected a given voltage is impressed from A to B the result of the voltage from A to C will be more than that impressed at A B if the leads have been properly brought out, and less than the voltage impressed at A B if they have not been properly brought out.

Transformer Connections

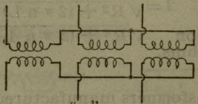
Delta-Delta Connection



Delta-Delta
Fig. 51

The voltage per transformer is the same as that between the line wires, the current per transformer is equal to the current per line wire divided by $\sqrt{3}$.

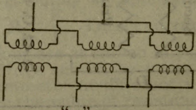
Star or Y Connection



Star or "Y" Connection
Fig. 52

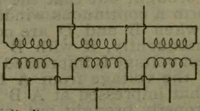
The current per transformer is the same as that per line wire; the voltage per transformer is equal to the voltage between wires divided by $\sqrt{3}$.

Delta-Y Connection



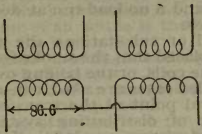
Delta-"Y" Connection
Fig. 53

Y-Delta Connection



"Y"-Delta-Connection
Fig. 54

T-Connection (Scott Transformer)



"*T*" Connection

Fig. 55

In this scheme the voltage impressed across one transformer is only 86.6 per cent. of that impressed across the other.

Method of Cooling Transformers

1. Self-cooling dry transformers.
2. Self-cooling oil filled transformers.
3. Transformer cooled by forced current of air.
4. Transformer cooled by forced current of water.
5. Transformer cooled by combinations of both.

Limiting Temperature Rise

The temperature rise should not exceed 50° C. in electric circuits by resistance and in other parts by thermometer.

Overload Capacity

Constant potential transformers, 25 per cent. for two hours, except in transformers connected to apparatus for which a different overload is guaranteed, in which case the same guarantee shall apply for the transformer as for the apparatus connected thereto.

Standard Ratios

It is recommended that the standard transformer ratios should be applicable to the following voltages, which are standard: 6600; 11,000; 22,000; 33,000; 44,000; 66,000; 88,000; 110,000.

The ratio will usually be an exact multiple of 5 or 10.

Rules for Installing and Operating Tranformers.

Must not be placed in any but metallic or other non-combustible cases. Must be constructed to comply with the following tests:

1. Shall be run for eight consecutive hours at full load in watts under conditions of service, and at the end of that time the rise in temperature, as measured by the increase of resistance of the primary coil shall not exceed 135° F.

2. The insulation of transformer when heated shall withstand continuously for five minutes a

difference of potential of 10,000 volts (alternating) between primary and secondary coils and core, and between the primary coils and core; also must withstand a no load run at double voltage for 30 minutes.

In Central or sub-stations the transformers must be so placed that the smoke from the burning out of the coils, or the boiling over of the oil, where oil filled cases are used, can do no harm.

The neutral point of the transformer or the neutral wire of distributing systems may be grounded and when grounded the following rules must be complied with.

1. Transformers feeding two wire systems must be grounded at the center of the secondary coils.

2. Transformers feeding systems with a neutral wire must have the neutral wire grounded at the transformer and at least every 250 ft. beyond.

In general, in order to obtain minimum operating costs, transformers of the present standard performances should be used on a load which will bring them up to the maximum safe temperature rise.

Constant Current Transformers

The Constant Current Transformer in its simplest type consists of a core of the double magnetic circuit type with three vertical legs and two coils placed around the central leg. The primary is fixed and the secondary is suspended and balanced by counter weights so that it can move up and down. A flow of current in the coils causes a repulsion between them, causing them to separate to the position for which they are balanced. An increase of current due to cutting out of series lamps, for example, causes them to separate farther, increasing the leakage and thereby cutting down the induction. With any current less than normal the repelling force diminishes, and the primary and secondary coils approach each other thereby restoring the current to its normal value.

The General Electric Company has recently designed a new edgewise wound transformer, with concentric coils and cruciform core, giving better efficiency, higher power factor and closer regulation. It is so designed that the short circuiting of the secondary at any time will not cause any serious damage. It will regulate from no load to full load within 1/10 of an ampere, above or below normal rated current on any primary voltage within 5 per cent of the normal rated value. By means of a slight adjustment it can be adapted for any secondary current within 7 1/2 per cent of normal rated value, thus allowing the customer to order lamps of other than exact standard values.

Trigonometric Functions and Rules.

1. The sine of an angle is the ratio of the opposite leg to the hypotenuse.
2. The cosine of an angle is the ratio of the adjacent leg to the hypotenuse.
3. The tangent of an angle is the ratio of the opposite leg to the adjacent.
4. The cotangent of an angle is the ratio of the adjacent leg to the opposite.
5. The secant of an angle is the ratio of the hypotenuse to the adjacent leg.
6. The cosecant of an angle is the ratio of the hypotenuse to the opposite leg.
7. The versed sine of an angle **a** is equal to 1 — cos **a.**
8. The coversed sine of an angle **a** is equal to 1 — sin **a.**

$$\text{Sin } x = \frac{1}{\csc x}; \quad \text{Cos } x = \frac{1}{\sec x}; \quad \text{Tan } x = \frac{1}{\cot x}$$

$$\text{Tan } x = \frac{\sin x}{\cos x}; \quad \text{Cot } x = \frac{\cos x}{\sin x}.$$

$$\sin^2 x + \cos^2 x = 1; \quad 1 + \tan^2 x = \sec^2 x;$$

$$1 + \cot^2 x = \csc^2 x.$$

$$\sin x = \cos \left\{ \frac{\pi}{2} - x \right\}; \quad \cos x = \sin \left\{ \frac{\pi}{2} - x \right\}$$

$$\tan x = \cot \left\{ \frac{\pi}{2} - x \right\}.$$

$$\sin(\pi - x) = \sin x; \quad \cos(\pi - x) = -\cos x;$$

$$\tan(\pi - x) = -\tan x$$

$$\sin(x + y) = \sin x \cos y + \cos x \sin y.$$

$$\sin(x - y) = \sin x \cos y - \cos x \sin y.$$

$$\cos(x + y) = \cos x \cos y - \sin x \sin y.$$

$$\tan(x + y) = \frac{\tan x + \tan y}{1 - \tan x \tan y}$$

$$\tan(x - y) = \frac{\tan x - \tan y}{1 + \tan x \tan y}$$

$$\sin 2x = 2 \sin x \cos x; \quad \cos 2x = \cos^2 x - \sin^2 x;$$

$$\tan 2x = \frac{2 \tan x}{1 - \tan^2 x}.$$

$$\sin x = 2 \sin \frac{x}{2} \cos \frac{x}{2}; \quad \cos x = \cos^2 \frac{x}{2} - \sin^2 \frac{x}{2}.$$

$$\tan x = \frac{2 \tan \frac{x}{2}}{1 - \tan^2 \frac{x}{2}}$$

$$\cos^2 x = \frac{1}{2} + \frac{1}{2} \cos 2x; \quad \sin^2 x = \frac{1}{2} - \frac{1}{2} \cos 2x.$$

$$1+\cos x = 2\cos^2\frac{x}{2};\quad 1-\cos x = 2\sin^2\frac{x}{2}.$$

$$\sin\frac{x}{2} = \pm\sqrt{\frac{1-\cos x}{2}};\quad \cos\frac{x}{2} = \pm\sqrt{\frac{1+\cos x}{2}};$$

$$\tan\frac{x}{2} = \pm\sqrt{\frac{1-\cos x}{1+\cos x}}$$

$$\sin x + \sin y = 2\sin\frac{1}{2}(x+y)\cos\frac{1}{2}(x-y)$$

$$\sin x - \sin y = 2\cos\frac{1}{2}(x+y)\sin\frac{1}{2}(x-y)$$

$$\cos x + \cos y = 2\cos\frac{1}{2}(x+y)\cos\frac{1}{2}(x-y)$$

$$\cos x - \cos y = -2\sin\frac{1}{2}(x+y)\sin\frac{1}{2}(x-y)$$

Law of sines

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Where A is the angle opposite side a
B is the angle opposite side b
C is the angle opposite side c

Law of cosines

$$a^2 = b^2 + c^2 - 2\,bc\cos A$$

The following table gives the signs for the trigonometric functions in the various quadrants:

Quadrant	sin	cos	tan	cot	sec	csc
First	+	+	+	+	+	+
Second	+	—	—	—	—	+
Third	—	—	+	+	—	—
Fourth	—	+	—	—	+	—

In the diagram below (Fig. 56) the functions are positive in quadrants denoted by arrows.

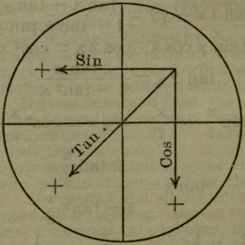
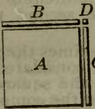


Fig. 56

Mensuration.

Square Root

The method of extracting square root is best shown by the use of an example: Find the square root of 2809, or, in other words, find the length of the side of a square which contains 2809 units:



	2809	53
	25	
2 x 50 = 100	309	
3		
103	309	

Fig. 57

First divide the number into periods of two figures each, starting from the decimal point. The square root will have one figure for each period in the square, so the side of this particular square will be represented by tens, and obviously by 5 tens since the largest square in 28 is 25. This square subtracted leaves 309 square units to be taken into account. These 309 square units can be divided up into three parts, consisting of two strips B and C, 50 units long and a smaller square D at the corner, whose dimensions we do not yet know. The combined length of B and C is 2 x 50, or 100, and 100 is contained in 309, 3 times. Now assuming the width of these strips to be 3 the area of the strips will be 300, and that of the square will be 9, making a total of 309 which completes the square.

Rule to be Followed in Extracting the Square Root of a Number.

Separate the number into periods of two figures each, beginning at the decimal point.

Find the greatest square in the left hand period and write its root for the first figure of the required root.

Square this root and subtract the result from the left hand period and annex to the remainder the next period for a dividend.

Double the root already found and multiply it by 10 for a trial divisor, and divide it into the dividend, making allowance for the fact that the dividend must contain in addition to the product of the trial divisor and the quotient obtained, the square of the quotient itself. Subtract this sum of the products from the dividend, annex to the remainder the next period, and proceed as before.

CUBE ROOT

Rule to be Followed in Extracting the Cube Root of a Number.

Separate the number into periods of three figures each, beginning at the decimal point.

Find the greatest cube in the left hand period and write its root for the first figure of the required root.

Cube this root, subtract the result from the left hand period and annex to the remainder the next period for a dividend.

Take three times the square of the root already found, consider it as tens for a trial divisor and divide it into the dividend. The quotient or the quotient diminished will be the second part of the root.

To this partial divisor add three times the product of the first part of the root, considered as tens by the second part, and also the square of the second part. Their sum will be the complete divisor.

Multiply the complete divisor by the second part of the root and subtract the product from the dividend. Continue this until all the figures of the root have been found.

Illustration and Explanation of the Above Rule

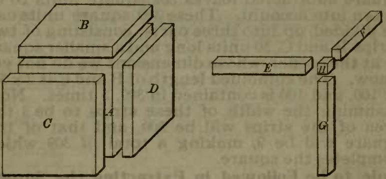


Fig. 58

Find edge of cube whose contents are 13,824 units.

	13824 | 24
	8
$3 \times 20^2 = 1200$	5824
$(4) \times 1200 = 4800$	
$(4) \times 4 \times 3 \times 20 = 960$	
$(4) \times 4 \times 4 = \quad 64$	5824
5824	

As there are two periods in this figure the root will be in the order of tens. The largest cube in the first period is 8. This subtracted from the number leaves 5,824 cubical units. This remainder must be composed of seven parts, C, B, D, E, F, G and H. The sum of the areas of the faces of C, B and D is $20^2 \times 3 = 1200$. This is contained in 5,824 four times. With this as a trial quotient we can now find the contents of the additional parts. The contents of C, B and D is $1200 \times 4 = 4800$; of E, F and G is $3 (4 \times 4 \times 20) = 960$; of H is $4^3 = 64$, making a total of 5,824.

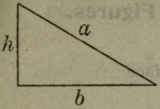


Fig. *a*

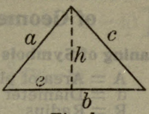


Fig. *b*

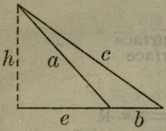


Fig. *c*

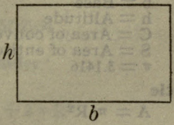


Fig. *d*

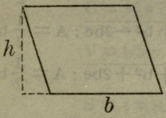


Fig. *e*

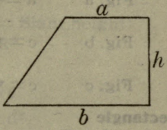


Fig. *f*

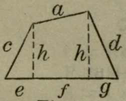


Fig. *g*

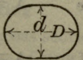


Fig. *h*

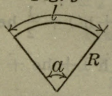


Fig. *i*

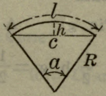


Fig. *j*

Formulæ for Finding Area and Volumes of Geometrical Figures.

Meaning of Symbols Used

A = Area of plane surface
d = Diameter
R = Radius
V = Volume
p = Perimeter
b = Base
h = Altitude
C = Area of convex surface
S = Area of entire surface
$\pi = 3.1416$

Circle

$A = \pi R^2$ $\qquad p = 2 \pi R$

Triangles

Fig. a $\qquad a = \sqrt{b^2 + h^2}$; $\qquad A = \frac{1}{2} bh$

Fig. b $\qquad c = \sqrt{a^2 + b^2 - 2be}$; $A = \frac{1}{2} bh$

Fig. c $\qquad c = \sqrt{a^2 + b^2 + 2be}$; $A = \frac{1}{2} bh$

Rectangle

Fig. d $\qquad A = hb$

Paralellogram

Fig. e $\qquad A = hb$

Trapezoid

Fig. f $\qquad A = \frac{1}{2} h (a + b)$

Trapezium

Fig. g $\qquad A = \frac{1}{2} f (h + h') + \frac{1}{2} he +$

$\frac{1}{2} h' g = \frac{1}{2} \left[f (h + h') + he + h' g \right]$

Ellipse

Fig. h $\qquad p = \sqrt{\frac{D^2 + d^2}{2} - \frac{D - d^2}{8.8}}$

$A = \frac{\pi}{4} D d$

Sector

Fig. i $\qquad A = \frac{1}{2} l R$

$l = \frac{a}{360} 2 \pi R$

$A = \frac{a \pi R^2}{360} = .008727 R^2 a$

Segment

Fig. j $A = \frac{1}{2}\left[lR - c\ (R-h)\right]$

$$A = \frac{\pi R^2 a}{360} \pm \frac{c}{2}(R-h)$$

$$l = \frac{\pi R a}{180} = .0175\ R\ a$$

$$a = \frac{180\ l}{\pi R} = 57.2956\ \frac{l}{R}$$

Cylinder

$C = \pi\ d\ h$
$S = 2\ \pi\ R\ h + 2\ \pi\ R^2$
$V = \pi\ R^2\ h$

Cone

$C = \frac{1}{2}\ \pi\ d\ l$ (l = Slant height)
$S = \pi\ R\ l + \pi\ R^2$
$V = 1/3\ \pi\ R^2\ h$

Sphere

$S = 4\ \pi\ R^2 = \pi\ d^2$

$V = 4/3\ R^3\ \pi = \frac{R \times S}{3}$

Circular Ring

r = Radius of cross section
R = Mean radius of ring
$S = 4\ \pi^2\ R\ r$
$V = 2\ \pi\ R\ r^2$

Frustum of a Cone

$C = \frac{\pi\ l}{2}\ (D + d)$ (d = Diameter of upper base; D = Diameter of lower base)

$$S = \frac{\pi\ l}{2}\ (D + d) + \frac{\pi}{4}\ (D^2 + d^2)$$

$$V = \frac{1}{12}\ \pi\ h\ (D^2 + D\ d + d^2)$$

Pyramid

l = Slant altitude
p = Perimeter of base
$C = 1/2\ p\ l$
$S = 1/2\ p\ l$ + area of base
$V = 1/3$ area of base $\times$ h

Frustum of a Pyramid

$C = 1/2\, l\,(P + p)$
$S = 1/2\,(P + p)\, l + A + a$
$V = 1/3\, h\,(A + a + \sqrt{A\,a})$
a = Area of upper base
A = Area of lower base
p = Perimeter of upper base
P = Perimeter of lower base

Centigrade and Fahrenheit Scales

Temperature

Centigrade	Fahrenheit	Centigrade	Fahrenheit
0	32	50	122
5	41	55	131
10	50	60	140
15	59	65	149
20	68	70	158
25	77	75	167
30	86	80	176
35	95	85	185
38	100.4	90	194
40	104	95	203
42	107.6	100	212
45	113		

Temp. C = 5/9 (Temp. F — 32)
Temp. F = 9/5 (Temp. C + 32)

32. Squares, Cubes, Square Roots, Cube Roots and Reciprocals.

No.	Squares	Cubes	Square Roots	Cube Roots	Reciprocals
1	1	1	1.0000	1.0000	1.0000
2	4	8	1.4142	1.2599	.5000
3	9	27	1.7320	1.4422	.3333
4	16	64	2.0000	1.5874	.2500
5	25	125	2.2360	1.7099	.2000
6	36	216	2.4494	1.8171	.1666
7	49	343	2.6457	1.9129	.1428
8	64	512	2.8284	2.0000	.1250
9	81	729	3.0000	2.0800	.1111
10	100	1000	3.1622	2.1544	.1000
11	121	1331	3.3166	2.2239	.0909
12	144	1728	3.4641	2.2894	.0833
13	169	2197	3 6055	2.3513	.0769
14	196	2744	3.7416	2.4101	.0714
15	225	3375	3.8729	2.4662	.0666
16	256	4096	4.0000	2.5198	.0625
17	289	4913	4.1231	2.5712	.0588
18	324	5832	4.2426	2.6207	.0555
19	361	6859	4.3588	2.6684	.0526
20	400	8000	4.4721	2.7144	.0500
21	441	9261	4.5825	2.7589	.0476
22	484	10648	4.6904	2.8020	.0454
23	529	12167	4.7958	2.8434	.0434
24	576	13824	4.8989	2.8844	.0416
25	625	15625	5.0000	2.9240	.0400
26	676	17576	5.0990	2.9624	.0384
27	729	19683	5.1961	3.0000	.0370
28	784	21952	5.2915	3.0365	.0357
29	841	24389	5.3851	3.0723	.0344
30	900	27000	5.4772	3.1072	.0333
31	961	29791	5.5677	3.1413	.0322
32	1024	32768	5.6568	3.1748	.0312
33	1089	35937	5.7445	3.2075	.0303
34	1156	39304	5.8309	3.2396	.0294
35	1225	42875	5.9160	3.2710	.0285
36	1296	46656	6.0000	3.3019	.0277
37	1369	50653	6.0827	3.3322	.0270
38	1444	54872	6.1644	3.3619	.0263
39	1521	59319	6.2444	3.3912	.0256
40	1600	64000	6.3245	3.4199	.0250
41	1681	68921	6.4031	3.4482	.0243
42	1764	74088	6.4807	3.4760	.0238
43	1849	79507	6.5574	3.5033	.0232
44	1936	85184	6.6332	3.5303	.0227
45	2025	91125	6.7082	3.5568	.0222
46	2116	97336	6.7823	3.5830	.0217
47	2209	103823	6.8556	3.6088	.0212
48	2304	110592	6.9282	3.6342	.0208
49	2401	117649	7.0000	3.6593	.0204

32. Squares, Cubes, Square Roots, Cube Roots and Reciprocals.—Continued.

No.	Squares	Cubes	Square Roots	Cube Roots	Recip-rocals
50	2500	125000	7.0710	3.6840	.0200
51	2601	132651	7.1414	3.7084	.0196
52	2704	140608	7.2111	3.7325	.0192
53	2809	148877	7.2801	3.7562	.0188
54	2916	157464	7.3484	3.7797	.0185
55	3025	166375	7.4161	3.8029	.0181
56	3136	175616	7.4833	3.8258	.0178
57	3249	185193	7.5498	3.8485	.0175
58	3364	195112	7.6157	3.8708	.0172
59	3481	205379	7.6811	3.8928	.0169
60	3600	216000	7.7459	3.9148	.0166
61	3721	226981	7.8102	3.9364	.0163
62	3844	238328	7.8740	3.9578	.0161
63	3969	250047	7.9372	3.9790	.0158
64	4096	262144	8.0000	4.0000	.0156
65	4225	274625	8.0622	4.0207	.0153
66	4356	287496	8.1240	4.0412	.0151
67	4489	300763	8.1853	4.0615	.0149
68	4624	314432	8.2462	4.0816	.0147
69	4761	328509	8.3066	4.1015	.0144
70	4900	343000	8.3666	4.1212	.0142
71	5041	357911	8.4261	4.1408	.0140
72	5184	373248	8.4852	4.1601	.0138
73	5329	389017	8.5444	4.1793	.0136
74	5476	405224	8.6023	4.1983	.0135
75	5625	421875	8.6602	4.2171	.0133
76	5776	438976	8.7177	4.2358	.0131
77	5929	456533	8.7749	4.2543	.0129
78	6084	474552	8.8317	4.2726	.0128
79	6241	493039	8.8881	4.2908	.0126
80	6400	512000	8.9442	4.3088	.0125
81	6561	531441	9.0000	4.3267	.0123
82	6724	551368	9.0553	4.3444	.0121
83	6889	571787	9.1104	4.3620	.0120
84	7056	592704	9.1651	4.3795	.0119
85	7225	614125	9.2195	4.3968	.0117
86	7396	636056	9.2736	4.4140	.0116
87	7569	658503	9.3273	4.4310	.0114
88	7744	681472	9.[illegible]808	4.4479	.0113
89	7921	704969	9.4339	4.4647	.0112
90	8100	729000	9.4868	4.4814	.0111
91	8281	753571	9.5393	4.4979	.0109
92	8464	778688	9.5916	4.5143	.0108
93	8649	804357	9.6436	4.5306	.0107
94	8836	830584	9.6953	4.5468	.0106
95	9025	857375	9.7467	4.5629	.0105
96	9216	884736	9.7975	4.5788	.0104
97	9409	912673	9.8488	4.5947	.0103
98	9604	941192	9.8994	4.6104	.0102
99	9801	970299	9.9498	4.6260	.0101
100	10000	1000000	10.0000	4.6415	.0100

Rates

The cost of generating and delivering electrical energy may be considered as divided into two parts,—running expenses and standing expenses: The running expenses comprise the cost of fuel, labor, repairs, supplies and water, and are proportional to the power used. The standing expenses consist of depreciation, interest and general expenses. The standing expenses may be regarded as fixed, yet they are dependent on the character of the load, or rather on the load factor. From 60 to 70 per cent. of the entire expense is represented by the standing expense so that the rate charge per kw-hr. will increase rapidly when conditions demand a high standing expense.

In adjusting rate schedules the following factors demand first consideration:— The consumer's "demand" on the capacity of his installation or connected load for drawing on the station; the number of hours use to which he puts his capacity; the "interweave" or variation in the consumer's use of service; the cost of generating the current itself. In any receiving installation it is probable that the consumer's demand will seldom reach the maximum of his installed capacity, yet when it does he wishes good service, and the central station must be able to supply it. Again, when the demand of any one class of consumers is highest the demand of the other consumers will probably be low. The aggregate of these variations is called the "interweave." If it were not for this interweave the central station would need equipment enough to meet the simultaneous demand of the total connected load on its lines. This would require a large investment in machinery equipment and help, which would necessarily be idle and non-productive at times. There are variations in interweaves, however, for different hours of the day and different seasons of the year, and the central station must be equipped to meet the maximum demand for the interweave. On this account the customer with a large installed capacity connected to the lines represents a standing expense to the station, irrespective of his use of current, and rates should be adjusted with this in mind.

The customer who uses his installation a large number of hours per day is more profitable to to the central station than the customer who uses a large amount of current for only a few hours. This is due to the fact that the portion of maximum demand on the central station that may be considered as reserved for this customer is producing returns in revenue for a greater number of hours, or, stating it in other terms, the equipment reserved for this customer is idle

a smaller number of hours, accordingly the loss due to investment on non-productive equipment is lowered.

The factors in rate adjusting vary to a great extent for different classes of service, and it is difficult to use any one schedule without apparent discrimination, favorable or unfavorable to some one of the different classes. In general, however, the object should be to charge for the service in direct proportion to the cost of serving.

Rate Schedules

Flat Rates

A fixed rate per kilowatt hour. This system does not provide a fair return to the company, neither does it encourage the profitable customer.

Rate Differentials

A lower rate is given for motors and battery charging than for lighting loads. This is advisable when these two classes of service are limited to the hours when otherwise a part of the equipment would be idle, although some classes of motor load, as elevators, etc., by their intermittent service, may seriously affect the lighting voltage.

Manchester or Hopkinson System

A fixed price is charged for each kilowatt of installed capacity, plus the price per kilowatt hour. The chief objection to this system is that it discourages the installation of lamps excepting where they are burned for long hours, or where they are considered a necessity. It also tends to make the cost of residential lighting unattractive.

Rate Discounts

A discount is given on the gross bills and also an additional discount based on the average use of the installation. The objection to this system is that the discount rate must evidently be divided into steps. In case of a 5% discount on a $100 bill the charge would be $95, while a bill for $98 would not be discounted, so that the first customer would get more energy for $95 than the second would get for $98.

Wright or Brighton Demand System

In this system the customer pays his equitable quota of the strictly fixed charges and also of the standby charges. These items are included in the charge per hour made for the first hour's use of the number of lamps equivalent to practically the maximum number of lamps used at any one time. For the energy used in excess of the first hour's average use of the maximum demand the customer pays a different rate proportional to the additional expense which the company is under in supplying him with additional energy.

Kapp System

The rate is based on the time of maximum demand of the consumer as compared with the time of the station's maximum load. The advantage of this system is that the customer, who for the same total current supplied to him contributes least to the station's maximum load, benefits most largely by discounts.

Wholesale or Bulk Supply

Energy is usually sold under a flat rate and at a reduced price. The reduction is due partly to the fact that a large supply can be furnished more cheaply per unit than a smaller supply. The chief reason for lowering the rate, however, is that this class of business is usually competitive and a lower rate must be given to obtain the contract.

Resuscitation From Electric Shock

FOLLOW THESE INSTRUCTIONS EVEN IF VICTIM APPEARS DEAD

I. Immediately break the circuit.

With a single quick motion, free the victim from the current. Use any **dry non-conductor** (clothing, rope, board) to move either the victim or the wire. Beware of using metal or any moist material. While freeing the victim from the live conductor have every effort also made to shut off the current quickly.

II. Instantly attend to the victim's breathing.

1. As soon as the victim is clear of the conductor, rapidly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.). Then **begin artificial respiration at once.** Do not stop to loosen the victim's clothing now; **every moment of delay is serious.** Proceed as follows:

(a) Lay the subject on his belly, with arms extended as straightforward as possible and with face to one side, so that nose and mouth are free for breathing. Let an assistant draw forward the subject's tongue.

(b) Kneel straddling the subject's thighs and facing his head; rest the palms of your hands on the loins (on the muscles of the small of the back), with fingers spread over the lowest ribs.

(c) With arms held straight, swing forward slowly so that the weight of your body is gradually, but **not violently,** brought to bear upon the subject. This act should take from two to three seconds.

Immediately swing backward so as to remove the pressure, thus returning to the first position.

(d) Repeat deliberately twelve to fifteen times a minute the swinging forward and back—a complete respiration in four or five seconds.

(e) As soon as this artificial respiration has been started, and while it is being continued, an assistant should loosen any tight clothing about the subject's neck, chest or waist.

2. Continue the artificial respiration (if necessary, at least an hour), **without interruption,** until natural breathing is restored, or until a physician arrives. If natural breathing stops after being restored, use artificial respiration again.

3. **Do not give any liquid by mouth until the subject is fully conscious.**

III. Send for nearest doctor as soon as accident is discovered.

A poster embodying the above rules has been published and distributed by the ELECTRICAL WORLD.

INDEX

General Electric Company

Principal Offices, Schenectady, N. Y.

General Sales Office
Edison Lamp Department,
Harrison, N. J.

SALES OFFICES
(Address nearest office)

BOSTON, MASS.....................................84 State Street
Springfield, Mass..............Massachusetts Mutual Building
Providence, R. I...........................Union Trust Building
NEW YORK, N. Y............................30 Church Street
Rochester, N. Y................................Granite Building
Syracuse, N. Y..........................Post-Standard Building
Buffalo, N. Y...........................Ellicott Square Building
Erie, Pa.......................Marine National Bank Building
New Haven, Conn.............................Malley Building
PHILADELPHIA, PA..... ....Witherspoon Building
Baltimore, Md...............................Electrical Building
Charlotte, N. C.................................Trust Building
Charleston, W. Va........Charleston National Bank Building
Pittsburgh, Pa.................................Oliver Building
Richmond, Va..................................Mutual Building
Youngstown, Ohio...............................Wick Building
ATLANTA, GA...............Third National Bank Building
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Seattle, Wash........... ....Colman Building
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For TEXAS and OKLAHOMA Business refer to
Hobson Electric Company
Dallas, Tex.......................Lamar & Caruth Streets
El Paso, Tex...........Chamber of Commerce Building
Houston, Tex..........................Chronicle Building
Oklahoma City, Okla.................Insurance Building

FOREIGN SALES OFFICES
Schenectady, N. Y., Foreign Dept.
New York, N. Y., 30 Church St.
London, E. C., England, 83 Cannon St.

For all CANADIAN Business refer to
Canadian General Electric Co., Ltd., Toronto, Ont.

Additional Data